SELECTED SOIL PROPERTIES AND VEGETATION COMPOSITION OF FIVE WETLAND SYSTEMS ON THE MAPUTALAND COASTAL PLAIN, KWAZULU-NATAL

by

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I, Mathilde Luïse Pretorius, declare that **Selected soil properties and vegetation composition of five wetland systems on the Maputaland Coastal Plain, Kwazulu-Natal** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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(Initials and Surname)

SUMMARY

South Africa has a few unique and understudied areas of interest regarding wetlands, of which the Maputaland Coastal Plain (MCP) is one. This is regarded as a large gap in scientific knowledge, especially since firstly, the MCP is regarded as a unique area in terms of biodiversity, geology, social history, and ecosystem variety; and secondly, wetlands are a vulnerable, and yet a greatly important ecosystem type in South Africa. Additionally the wetlands on the aeolian derived sandy soils associated with the MCP are problematic to delineate. Although the wetland delineation guideline of DWAF (2005) gives a list of criteria to aid the delineation process on sandy coastal aquifers, this has never been scientifically reviewed. The aim of this study was to investigate how vegetation and soil properties vary down the topographical slope in various wetland types on the MCP. This was done in order to contribute to the knowledge base and understanding of wetlands in this area, as well as to determine whether differences between zones are significant enough to be used as indicators of wetland boundaries. Soil colour was investigated as a possible new delineation indicator. A section is also devoted to commentary on the current wetland delineation procedure on the MCP. This study shows that wetland types on the MCP are very distinct from each other, and therefore broad statements about the soil and vegetation characteristics of wetlands are discouraged. Three substrate types namely high organic-, duplex-, and sandy substrates dominate wetlands on the MCP. These play a major influential role in the general characteristics and function of the wetland types. Contrary to popular belief, redoximorphic accumulation and -depletions do occur on the MCP, but are often inconsistent in their presence. Chemical soil properties were found not to be good indicators of wetland boundaries on the MCP, although certain patterns can be discerned and applied to determine wetland conditions. The main drivers of wetland vegetation are the wetness- and productivity gradients. A few prominent indicator species can be used for the identification of wetland and non-wetland sites specifically on the MCP. Additionally, a relatively underutilised vegetation assessment procedure called Weighted Averaging was investigated, and can in most cases effectively discern between wetland and non-wetland conditions. This is a useful tool to apply in delineation practices in addition to other indicators. Soil colour can be used to successfully indicate wetland boundaries, and therefore be used as an additional wetland indicator. However, the method requires further testing and refinement for different wetland types. In general the vegetation and soil indicators do not correlate perfectly, and therefore delineation by means of one indicator only is greatly discouraged. An investigation of recommended delineation procedures for the MCP shows that new information on the understanding of wetlands in sandy coastal aquifers urgently needs to be disseminated. Approaches such as that of the USDA-NRCS where regionally specific guidelines are designed to be adapted regularly as new information becomes available, as well as the development of sets of hydric indicators specific to problematic areas, are recommended.

Key words: Indicators, Maputaland Coastal Plain, Soil, Vegetation, Wetland delineation.

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Dedicated to the voiceless of eManguzi, from whom I have learnt so much. May this research contribute in some manner to your environment and everyday lives, in due course.

Above all, this piece of work was completed only by grace of my Creator and Father. All honour to You.

"I will open rivers in bare places, and fountains in the midst of valleys; I will make the desert for a pool of water, and the dry land springs of water … so that they may see, and know, and set up, and understand together, that the hand of the LORD has done this; and the Holy One of Israel has created it."

Isa 41: 18 & 20

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ABBREVIATIONS

ADE	Aquifer Dependant Ecosystem
CCA	Canonical Correspondence Analysis
CEC	Cation Exchange Capacity
DCA	Detrended Correspondence Analysis
DP Type	The Utilised Perched Pans wetland type
EC	Electrical conductivity
HGM unit	Hydrogeomorphological unit
IDD	The Interdunal Depressions wetland type
ISA	Indicator Species Analysis
IV	Indicator Value
MCA	Maputaland Coastal Aquifer
MCP	Maputaland Coastal Plain
MS Type	The Muzi Swamp wetland type
PAs	Protected Areas
PL	The Moist Grassland wetland type
PP Type	The Tembe Elephant Park Perched Pans wetland type
PSA	Particle Size Analysis
SOC	Soil Organic Carbon
SOM	Soil organic matter
TEP	Tembe Elephant Park
WA	Weighted Averaging

Chapter 1
INTRODUCTION

1.1 Background

Wetlands are regarded internationally as one of the most important and productive, but also most sensitive ecosystems. These dynamic ecosystems deliver a variety of functions and services (Mitsch & Gosselink 2000, RAMSAR Convention on Wetlands 1971). With an average annual rainfall of 450 mm a year compared with the world average of about 860 mm (Schulze 1997), South Africa is regarded as a semi-arid country. Wetlands are therefore invaluable ecosystems in the maintenance of our water availability and supply in the environment. This value alone merits intensive focus on a variety of aspects of wetland ecosystems from South African research institutions. Being a water-poor country South African wetlands are also expressed in the environment in a quite different manner than in other parts of the world. Seasonal and temporary wetlands are a common feature in the South African landscape. These temporary wetlands, also called cryptic wetlands, are remarkably varied, and extremely vulnerable to destruction due to the difficulty in identifying and thus managing and conserving these (Day et al. 2010).

South Africa has a few unique and understudied areas of interest regarding wetlands, of which the Maputaland Coastal Plain (MCP) is one. The MCP is acknowledged worldwide for its distinct geological history (Ramsay & Cooper 2002, Watkeys et al. 1993, Wright et al. 2000, Maud 1980), unique social structure and history (Mountain 1990), rich biodiversity (Van Wyk 1996), diverse ecosystems (Matthews et al. 2001; Van Wyk & Smith 2001), and internationally recognized wetlands (such as Lake St. Lucia and the Kosi Bay lake system). The KwaZulu-Natal Province, within which the MCP is located, has the highest percentage of wetland areas per province area, as well as the second highest wetland surface area (hectares) in South Africa (SANBI 2010). The MCP itself consists of many different types of surface water bodies such as rivers, floodplains, estuaries, swamps, pans, and coastal lakes. Sieben (2014) states that the MCP "seems to be one of the richest areas of wetlands in the country, not only in terms of the various types, but also in terms of sheer extent, and it has been one of the first areas where research on wetland vegetation types took place". Currently Maputaland is under severe pressure as a result of anthropological pressures, informal afforestation, and a cyclic drought period (Faul et al. 2016, Grundling et al. 2014, Pretorius 2014).

As early as the late 1970s and early 1980s suggestions that South African wetlands were disregarded in terms of conservation and management, and showed widespread evidence of loss and degradation were documented (Phillips & Madlokazi 2011, Begg 1986, Noble and Hemens 1978). Despite earlier attempts to establish research programmes, research into wetlands during the 1990s was minimal. However, by the early 2000s progress was made in the development of wetland management programmes as a result of international obligations, policy and legislation (Phillips & Madlokazi 2011). The increased focus on the necessity of wetland management and conservation led to a need for some form of guidance on the identification and delineation of wetlands. In 1999 the Department of Water Affairs and Forestry - in collaboration with environmental managers, hydrologists, ecologists, non-government organisations, the private- and forestry sector, universities, and national and provincial government – produced the draft guidelines on the delineation of wetlands and riparian areas (DWAF 1999). This draft was improved in 2003 before the official guideline in its current form (DWAF 2005) was published. Much of the initiation of this process was as a result of the Rennies Wetland Project (later the Mondi Wetlands Programme) (N. Fourie pers. comm. 2016). Since then the importance of wetland conservation and management has become increasingly acknowledged among all sectors in South Africa, and the wetland community has grown rapidly. However, despite the excellent pieces of legislation (e.g. the National Water Act (Act 36 of 1998) (DWAF 1998)) and the great variety of other decision-making tools (e.g. the WET-Management Series) which aim to manage and conserve these ecosystems, wetlands in South Africa are still being destroyed at an alarming rate due to ignorance, mismanagement, and a lack of proper ecological understanding. The aim of the wetland delineation manual of DWAF (2005) was to give a baseline for consultants and practitioners to be able to identify wetlands and their wetness zones by investigating the topography, soil, and vegetation indicators. This document, however, is a guideline, and not a scientific document. It was produced based on the experience of a group of professionals, but does not contain or reflect physical data collected on various wetland types. Although it supplies a brief explanation of 'problematic areas', the main aim of the document is rather to create an umbrella of textbook characteristics by which most wetlands can be assessed. Currently wetland identification and delineation is a controversial, and much debated issue amongst the wetland community in South Africa. There has since been attempts to update and expand the guideline, as well as provide more scientifically based information, but to date there has not yet been a published document. Regardless, despite the shortcomings and controversy in the science behind wetland delineation, it is at this time still one of the most important tools in decision-making regarding wetland conservation.

Despite the recognition of the importance of these ecosystem services, wetlands remain among the most threatened habitats in the world (Millennium Ecosystem Assessment 2005, RAMSAR Convention 1971). Wetlands are the most threatened of all South Africa's ecosystems, with 65% of wetlands being critically endangered, endangered or vulnerable, of which 48% are critically endangered (Nel & Driver 2012). The situation on the MCP is no different. The wetlands on the MCP are mainly degraded as a result of aquifer draw-down through drought and land-use activities such as agriculture, forestry and urbanisation (Faul et al. 2016, Grundling 2014, Pretorius 2011).

The M.Sc. preceding this PhD focused on the vegetation composition of wetlands on the MCP. The research during this study generated much additional data, identified numerous gaps in current the knowledge and understanding of wetlands on the MCP, and initiated many new research questions - especially regarding relationships between vegetation and localized environmental conditions, and the differences between the various wetness zones in a wetland.

1.2 Rationale

Very few investigative studies into the soil and vegetation characteristics of specifically wetlands exist on the Maputaland Coastal Plain (MCP). This is regarded as a large gap in scientific knowledge, especially since firstly, the MCP is regarded as such a unique area in terms of biodiversity, geology, social history, and ecosystem variety; and secondly, wetlands are a vulnerable, and yet such a greatly important ecosystem type in South Africa.

Additionally, the wetland community in South Africa currently lacks concrete research data and understanding on how wetland properties vary down the topographical slope in wetlands on sandy coastal aquifers. The wetland delineation guideline (DWAF 2005) delineates wetland boundaries using terrain unit-, soil-, and vegetation indicators in three wetness zones, and identifies areas in the country where wetland delineation is not that straightforward. The wetlands occurring on the aeolian derived sandy soils associated with the Maputaland Coastal Aquifer (also known as the Maputaland Coastal Plain (MCP)) are problematic to delineate using the soil form and -wetness indicator. The soil on the MCP often exhibits grey profile colours not necessarily associated with waterlogged conditions, and also supposedly lacks the expected redoximorphic features used for identification of wetlands. Although the wetland delineation guideline of DWAF (2005) recommends a list of criteria to aid the delineation process on sandy coastal aquifers, this has never been scientifically reviewed.

1.3 Aim

The aim of this study was to investigate how vegetation and soil properties vary down the topographical slope in various wetland types on the MCP. This was done in order to contribute to the knowledge base and understanding of wetlands in this area, as well as to determine whether differences between zones are significant enough to be used as indicators of wetland boundaries. A potential new indicator, soil colour, was investigated to aid wetland delineation on the MCP. A chapter is also devoted to commentary on the current procedure of wetland delineation on the MCP.

1.4 Objectives

- To establish the typical soil characteristics of five different wetland types down a topographical gradient;
- To determine whether significant differences of the variation of soil properties down a topographical slope exist and can indicate wetland boundaries;
- To determine whether the fidelity of plant species to wetland conditions can indicate wetland boundaries;
- To determine whether soil colour changes down a topographical slope can indicate wetland boundaries.

1.5 Thesis exposition

Chapter 1 is the introductory chapter providing the background, rationale, aim, and objectives of the study.

Chapter 2 introduces the Maputaland Coastal Plain (MCP) as the study area.

Chapter 3 reviews the current literature on the various topics addressed in the dissertation, namely wetland delineation on the MCP, soil types found on the MCP, the general biogeochemistry of wetland soil, and the relationship between vegetation and environmental attributes, as well as vegetation as indicators of wetlands.

Chapter 4 details the methods followed to achieve the objectives.

Chapter 5 is the first results chapter, and is an in-depth examination of the change of selected soil properties down the topographical gradient in the various wetland types.

Chapter 6 compares the change of selected soil properties on the different positions on the topographical gradient to determine whether the differences can significantly indicate wetland boundaries.

Chapter 7 analyses vegetation data using approaches to elucidate the relationship between vegetation and environmental factors, to determine the presence of indicator species, and to determine the fidelity of 'wet' species to wetlands.

Chapter 8 investigates the relationship between soil organic carbon and soil colour to determine whether there is a correlation, and whether soil colour can be used as an indicator of wetland boundaries.

Chapter 9 combines the findings of the previous chapters to discuss the applicability of the various soil and vegetation properties as indicators of wetland boundaries. This chapter also reviews and comments on the national wetland delineation guideline of DWAF (2005).

Chapter 10: The final chapter concludes the dissertation. It makes recommendations and identifies current research gaps.

Chapter 2
STUDY AREA

2.1 Locality

Many names exist for the study area, with differences in opinion and much debate on the most appropriate one. The area comprises a large part of the Umkhanyakude District Municipality, and is unofficially regarded as Maputaland (previously known as Tongaland) (Mountain 1990). The current, widely accepted geographical boundaries for Maputaland are the Lebombo Range in the west, the St. Lucia Lake system in the south, the Indian Ocean in the east, and Maputo in the north (Matthews 2007, Mountain 1990, Bruton 1980a) (Figure 2.1). The definition and accuracy of the name Maputaland, as well as the exact boundaries of the area is, however, a matter of debate (Bruton 1980a), one which shall not be entered into in this study.

While the name Maputaland is a term used to define a political district of approximately 10 000 km^2 (Matthews 2007), natural scientists often use various other names to describe the ecologically unique north-eastern coastal plain of KwaZulu-Natal. These names vary considerably between publications. Many publications refer to the area bluntly as the north-eastern KwaZulu Natal plain (Wright et al. 2000). Ecologists may refer to this area with its high levels of endemism as the 'Maputaland Centre' (Van Wyk & Smith 2001, Van Wyk 1996), while hydrologists refer to the area by means of its hydrological characteristics as the '(Maputaland) Coastal Aquifer' (Grundling 2009, Vaeret 2008). The name 'Maputaland Coastal Plain' (MCP) (also regarded as the Zululand Coastal Plain in some instances (Meyer, et al. 2001, Thamm et al. 1996, Hobday 1979)), is used most often, and is used in this study to describe the area from Kosi-Bay in the north to the town of Mtunzini in the south. The Indian Ocean forms the eastern boundary, the Lebombo Mountains the north-western boundary, and the N2 the south-western boundary (Figure 2.2).

Although this study focuses on the northern parts of the MCP, specifically the area between the southern parts of Tembe Elephant Park (TEP) and the third Kosi-Bay lake, Lake Nhlange, this chapter will deal with the MCP as a whole. The reason for this is threefold:

- The MCP has a unique evolution history resulting in an area so ecologically distinctive from other parts in South Africa that it merits discussion;
- Most literature on the area concerns the MCP as a unit;
- Although many studies have been done in the conservation areas on the MCP, very little detailed environmental data exist for the stretch of rural area between the TEP in the west and the iSimangaliso Wetland Park in the east.

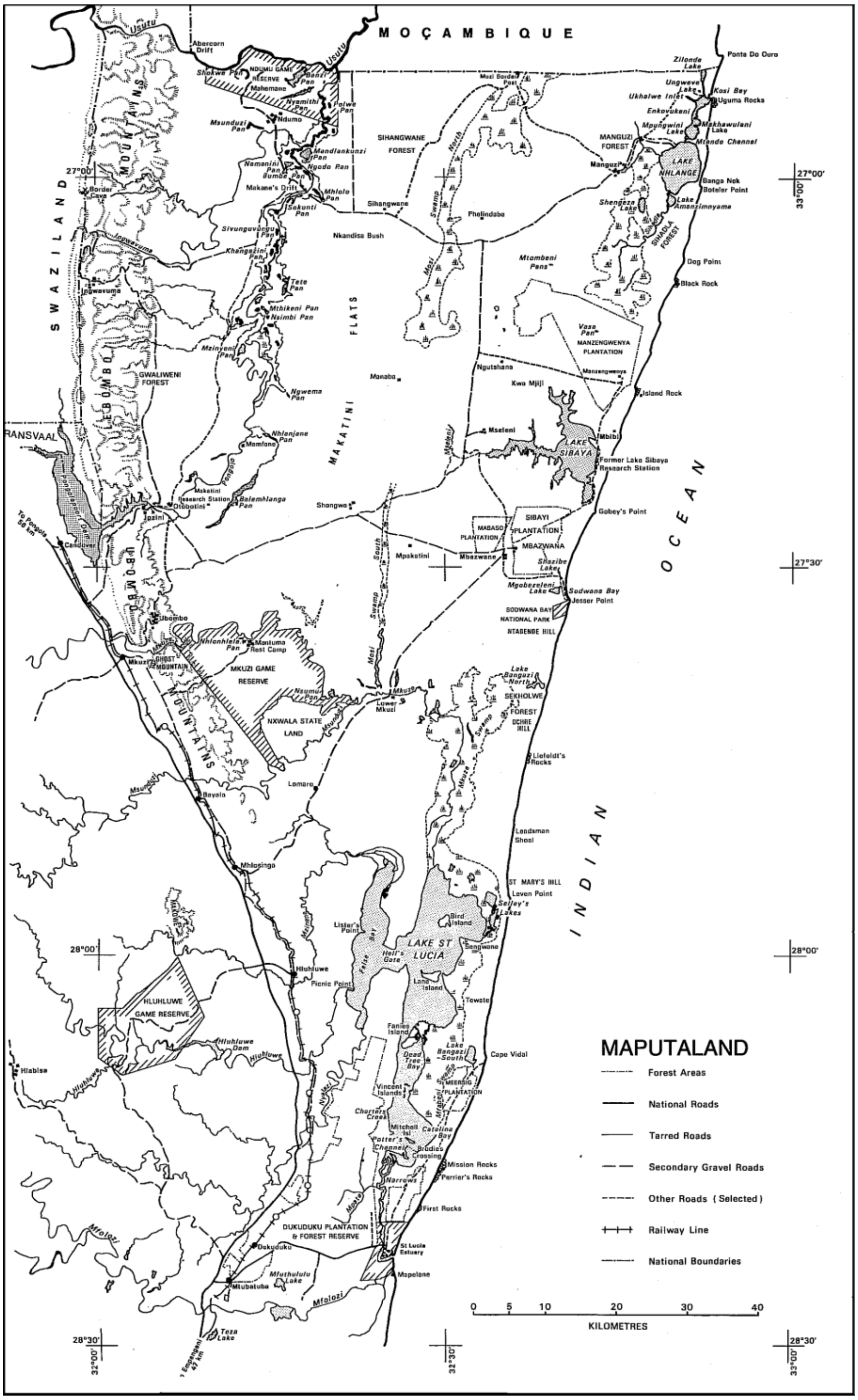

Figure 2.1. Map of Maputaland (Bruton & Cooper 1980).

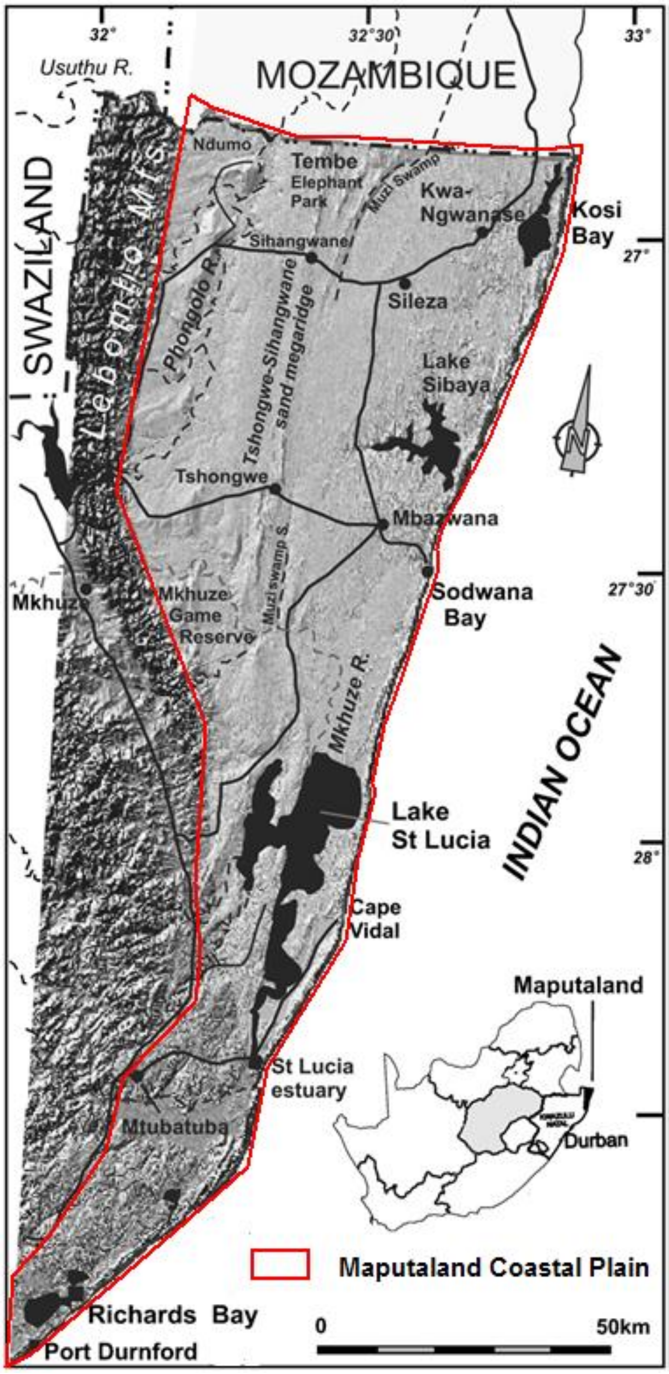

Figure 2.2. Maputaland Coastal Plain (Botha & Porat 2007).

2.2 Climate

2.2.1 Temperature

The coastal belt of the MCP falls within the moist subtropical climate zone of Africa due to the low-lying topography of the Mozambican coastal plain, as well as the warming influence of the Agulhas current. A short distance inland the area is regarded as dry subtropical, due to the decrease in precipitation (Matthews 2007, Watkeys et al. 1993, Maud 1980). The area is dominated by the South Atlantic and South Indian high pressure cells of the atmospheric general circulation patterns (Botha & Porat 2007). Summers tend to be very hot, but winters are mild. Relative humidity is very high and while it usually fluctuates between 65 - 85% (Matthews 2007), it may exceed 90% in the summer (Watkeys et al. 1993). The temperature along the Lebombo foothills varies between 18.1˚C and 26.3˚C, with an annual average of 22.7 ˚C. Along the coast temperatures vary between 11.5˚C and 28.7˚C, with an average temperature of 21.6 ˚C (Watkeys et al, 1993, Maud, 1980).

2.2.2 Precipitation

The MCP receives 60% of its rainfall during summer (November – February) and 40% of its rainfall during winter (April - September), with the mean annual precipitation of 963 mm (Matthews 2007, Mucina & Rutherford 2006) (Figure 2.3). There is a steep declining rainfall gradient from east to west, with an approximate mean of 1200 mm at the coast to 800–1000 mm at the crest of the Lebombo Mountains, with the lowest rainfall at 650 mm occurring at Mkhuze (Kelbe & Germishuyse 2010, Watkeys et al. 1993, Maud 1980). Episodic floods may occur due to the movement of tropical cyclones down the coast of the Mozambique Channel and cut-off low pressure systems (Matthews 2007).

a) **b)**

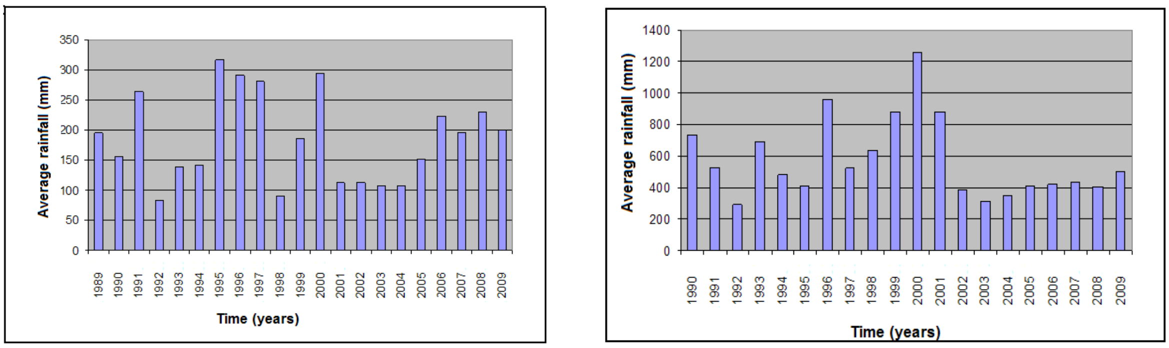

Figure 2.3. Average a) winter, and b) summer rainfall over 19 years on the northern section of the MCP (Grundling & Grundling 2010)

2.2.3 Winds and evaporation

Closer to the coastal areas the heat is somewhat relieved by the north-easterly winds blowing parallel to the coast. During winter south-westerly winds dominate, with more offshore westerly breezes (Watkeys et al. 1993). The prevailing winds from the north-east and south-west are strongest at the coast where dune topography and vegetation influence the wind direction and speed across the coastal plain. Evaporation rates are high in the winter and early spring. Annual average evaporation is approximately 1300 mm at the coastal areas and 1660 mm in the drier interior areas (Van Wyk & Smith 2001, Midgley et al. 1994, Watkeys et al. 1993).

2.2.4 Fire

Fire is a crucial component of the proper functioning of many of the vegetation types on the MCP, especially coastal grasslands (Van Wyk & Smith 2001). According to Matthews (2007), topography, regular fire and water table depth are the key ecological determinants. Although the woodlands on the MCP also experience and are adapted to regular fire, the sensitive and endangered Sand Forest vegetation type does not respond well to fire at all. Dune Forest is also not adapted to fire, but in the rare cases where fire does occur this vegetation type has the capacity to recover and re-establish itself relatively soon after the damage (Matthews 2007).

2.3 Topography

The MCP is a nearly flat, low-level coastal plain with undulating dune topography located roughly at 45 - 70 m above main sea-level (Mucina & Rutherford 2006). Maximum elevation is approximately 150 m, with the exception of the Lebombo range which rises to an elevation of approximately 600 m (Maud 1980). Ancient linear dunes of maximum 129 m elevation occur in the central part of the coastal plain. The highest vegetated dunes (200 m a.s.l.) in the world are found along the shoreline of the MCP (Matthews 2007, Van Wyk & Smith 2001, Maud 1980).

Three major natural lakes occur along the coastline of the MCP, namely Lake St Lucia, Lake Sibaya and the four interconnected Kosi-Bay Lakes (Matthews 2007, Wright et al. 2000). A number of smaller water bodies occur throughout the MCP with a great variety of associated extensive wetland systems, especially between the dune ridges (Begg 1986).

2.4 Geomorphology

In the west the MCP is characterized by the linear north-south Lebombo Range. In the east the coastal plain is separated from the Indian Ocean by a largely uninterrupted barrier dune complex. Located between the Lebombo Range and the coastal barrier dunes stretches a long, relatively flat coastal plain (70 km wide in places) with dune cordons interspersed with various wetland types such as floodplains, lakes, fens, swamp forests and pans (Grundling & Grundling 2010, Watkeys et al. 1993).

The following account is taken from Watkeys et al. (1993), except where mentioned otherwise. The MCP may be subdivided into five major terrestrial and aquatic landscape units:

- The gently undulating terrain at the base of the Lebombo Mountains;
- Sandy ridges (relict coastal dunes);
- Coastal lake systems;
- Coastal dunes; and
- River-related systems.

The Lebombo Mountain Range is at the widest and highest in the north, and consists of an undulating plateau at 300 - 600 m a.s.l., with a steep western scarp face and a gentle slope to the east. Incised into this range are various steep valleys. The northern rivers (Usuthu, Ngwavuma and

Pongolo) cut fairly straight valleys, whereas the Mkuze and Msunduze rivers meander through the Lebombo Range. The rivers of the MCP originate as large rivers with headwaters that lie west of the Lebombo Range, or as smaller streams which originate in the Lebombo Range, or as streams which originate as seepage areas within the sandy ridges and dunes on the coastal plain area. Most of the largest rivers of the coastal plain are non-perennial, flowing only during the rainy season and usually drying up by mid-winter. In the floodplains, the meandering channels with low gradients and high suspended loads are raised above the level of the adjacent floodplain by deposition of sediment to form levees. These are stabilised by vegetation until breaching occurs during flood events, causing a shift of the system. This process has resulted in the formation of the pans in the region. These rivers have been deflected by the north-south trending sandy ridges of the MCP. The numerous, relatively recent, palaeo-dune cordons are of fluvial and aeolian origin and are predominantly fine-grained and unconsolidated. The dune cordon separating the high energy shoreline from the true coastal lakes (namely Sibaya Lake, the Kosi Lakes, and Lake St. Lucia) is the youngest dune cordon and stretches uninterruptedly from the most southern tip of the MCP (Port Durnford) to the Mozambique border in the north (Meyer et al. 2001). These estuarine-linked lakes are actually remnants of much larger systems that have expanded and contracted numerous times in the past 6000 years. The mouths of these estuaries still prove to be extremely dynamic.

2.5 Geology

The MCP has had a complex geological evolution, and especially the Cenozoic evolution is poorly understood (Wright et al. 2000). Research into this topic is made difficult by, amongst others, extensive reworking of the sand cover on the MCP as well as little suitable dating material such as rock outcrops and fossil evidence (Wright et al. 2000). According to the study of Wright et al. (2000), scientists have attempted to clarify the stratigraphy in a number of works over the past 30 years. The most recent research on the geological evolution of the MCP has been done by Botha (2007).

The MCP as it is known today formed when the rhyolitic volcanic lavas from the Lebombo Range underlying the coastal plain were steeply tilted eastward in the late Mesozoic and Cenozoic period shortly before the disruption of the super-continent Gondwanaland (Botha & Porat 2006, Maud & Botha 2000, Maud 1980). This was followed by a layer of Cretaceous marine sediments, sedimentary rock and conglomerates in a wedge-like formation thickening from west to east to form the present day level coastal plain (Watkeys et al. 1993, Maud 1980). Following the deposition of the Cretaceous sediments, a long period of erosion followed, resulting in the deposition of shallow marine and terrestrial sediments. Constant worldwide sea-level fluctuations, marking the end of the Cretaceous period through the Tertiary and Quaternary, repeatedly exposed and submerged the MCP as the African continental edge changed and sea levels rose and fell (Maud & Botha 2000). These cycles of sedimentation and erosion resulted in most of the MCP to be covered in infertile sands, and are known as the Tertiary sediments formation. This layer is flat-lying and no more than 30 m thick. Following the Tertiary period of deposition, sedimentation, and erosion, the 50 m thick Port Durnford Beds were deposited. From the Pleistocene period until recently this surface has been reworked by wind-action, resulting in the MCP as it is known today, with its characteristic extensive dune topography of grey sand and the series of north-south aligned parabolic dune ridges parallel to the present day coastline (Maud 1980). These parabolic dune ridges make up the KwaMbonambi

Formation (Botha & Porat 2007). A rise in the groundwater table and resulting vegetation growth during the climatic optimum of the Holocene period stabilized the sand substrate. Hobday (1979) classifies the wetlands investigated in this study as 'Holocene marshes'.

The geological result of the various periods in time is visible in different parts of the MCP. The resistant volcanic rhyolites can still be seen in the Lebombo Range today, while the Cretaceous sediments are well exposed on the banks of the Pongolo River (Maud 1980). The Tertiary sediments are exposed as high dunes of reddish-brown sandy and clayey sand (the Berea Red Sands) in various parts of the MCP. Outwash gravels from the Lebombo Range overlying the Cretaceous sediments filled incised river valleys, resulting in the fertile alluvial material along drainage lines and floodplains (Maud 1980). Middle to Late Pleistocene coastal lake organic-rich mud (from the Port Durnford Formation) and the overlying aeolian sands (from the Kosi-Bay Formation) are exposed along sections of the coastline. Where the clay-enriched Kosi-Bay Formation is exposed in bottomlands, the near-surface water table is perched, creating expansive wetlands in the catchment areas of Lake Sibaya and the Kosi-Bay lakes (Botha & Porat 2007). The young, steep-sided dunes along the coast from the Pleistocene and Recent Age overlie the Port Durnford Beds as well as the coastal sandy limestone which formed in certain areas. These dunes are only stabilized by means of vegetation cover (Maud 1980).

The main formations on the MCP are as follows (Table 2.1) (Matthews 2007, Wright 2002, Watkeys et al*.* 1993):

Jurassic era (Lebombo Group)

- Jozini Formation (Volcanic rhyolites) (~179 Ma)

Cretaceous era (Zululand Group)

- Msunduze, Mpilo and Movene Formations (conglomerates and basalts) (155-135 Ma)
- Makatini Formation (the alluvial, fluvial, and marine sediments) (120-114 Ma)
- Mzinene Formation (marine silts and sand – pebbly with shelly concretions) (112-91 Ma)
- St Lucia Formation (rich in invertebrate fossils) (85-64 Ma)

Tertiary sub-era (Maputaland Group)

Miocene to Pliocene period (Figure 2.4)

- This period, characterized by the Uloa Formation, is challenging as little formation records are available and large time gaps with little or no information exists. It is known, however, that this period is marked by a series of sea level fluctuations. Remnants of dune cordons are still evident and now form the deeply weathered Berea Red sands.

Quaternary sub-era (Maputaland Group)

Pleistocene and Holocene period (1.8-0 Ma) (Figure 2.4)

- The Port Durnford Formation consists of estuarine clays, lacustrine deposits, peat, aeolian sediments, and various fossils, molluscs and foraminifera. This formation seems to correspond to inland water bodies, vleis, swamp forest, sediments with animal tracks (Matthews 2007)

- The Kosi-Bay Formation consists of the grey, weathered dune sands found inland of the coastal zone (Mid- to late Pleistocene period).
- The KwaMbonambi Formation comprises the series of dune systems derived from aeolian redistributed sands from older dunes. This formation is associated with the marine regression, and the associated incised river channels.
- The Sibayi Formation is a result of the Mid-Holocene marine transgression which flooded coastal valleys and lakes, leaving the high coastal dune cordon including the current dunes consisting of calcareous sands

Table 2.1. Stratigraphic column for the MCP (Watkeys et al. 1993).

Era	Sub-Era	Period	Epoch	Group	Formation
Cenozoic	Quaternary	Pleistocene	Holocene	Maputaland	Sibayi Formation (Redistributed sand)
					KwaMbonambi Formation (High dune sand)
			Pleistocene		Kosi-Bay Formation (Unconsolidated dune sand)
					Port Durnford Formation
	Tertiary	Pliocene to Miocene	Early Late		Calcarenite
					Pecten Beds and Uloa Formation
Mesozoic		Cretaceous	Late	Zululand	St. Lucia Formation
			Early		Mzinene Formation
					Makatini Formation
					Bumbeni Complex
					Mpilo and Movene Formation
					Msunduze Formation
		Jurassic	Middle	Lebombo	Jozini Formation

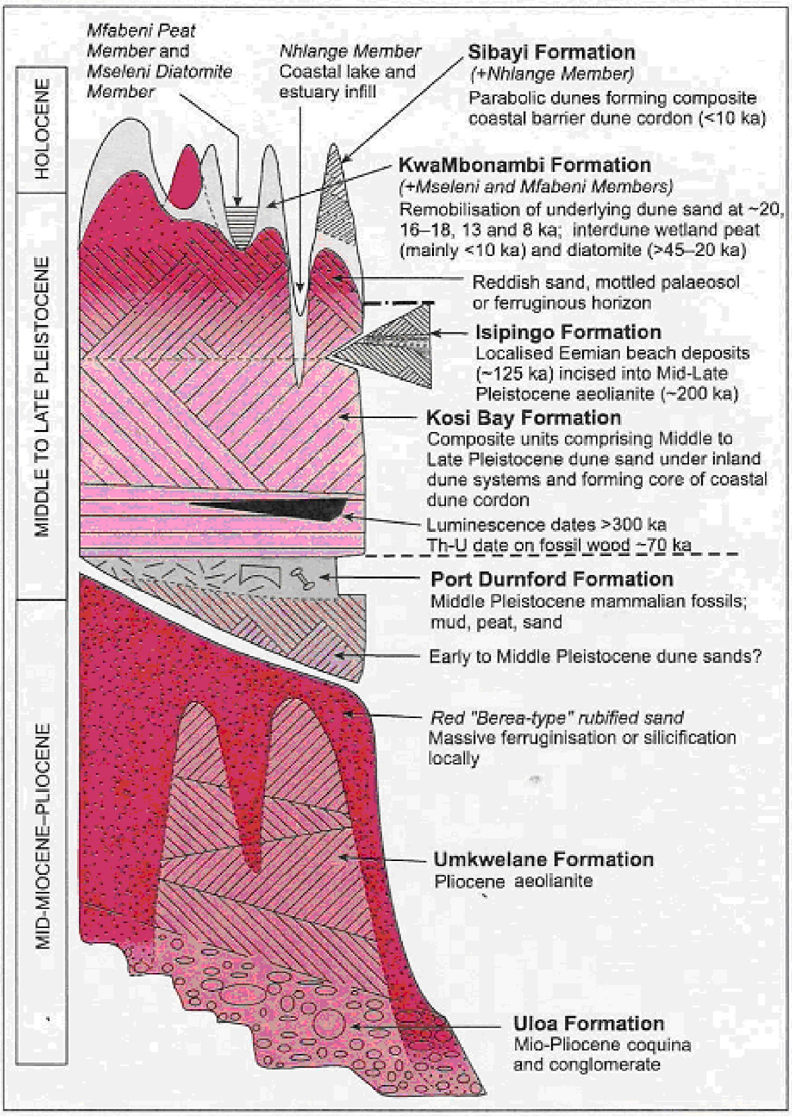

Figure 2.4 Idealised composite section of the Maputaland Group (Botha & Porat 2007).

2.6 Soil

As a result of the geological history of the MCP, a number of generations are preserved, complicating the understanding of the soils in the area (Watkeys et al. 1993). Strong relations exist between soils and the underlying geology, geomorphology, position, and hydrology (Grundling & Grundling 2010, Matthews et al. 1999), and these edaphic conditions, in addition with the high rainfall, have a strong influence on the biophysics of the system (Van Wyk & Smith 2001). According to Watkeys et al. (1993), the nature of the parent material has a dominant influence over other soil-forming factors, especially in the volcanic soils and dune sands.

Except for the relatively fertile, clayey soils of the Lebombo Range, the MCP is mainly covered by aeolian distributed sand from the Tertiary and Quaternary eras (Figure 2.5). As a result of this, the area is characterized by a combination of physical and chemical properties responsible for an infertile and low-productivity soil (Maud 1980). As a result of these highly permeable soils, high rainfall patterns in the area, and low water gradients, groundwater moves rapidly through the system and soils thus reflect a young chemistry with restricted vertical mixing (Kelbe & Germishuyse 2010). To the eastern seaboard where rainfall increases substantially, the soils are more leached and thus even more infertile, especially on the dune areas. Water typically leaches through these sandy soils quickly, collecting in the interdune depressions occurring along the coast of the MCP. The watertable in these interdune depressions is perched on the surface of the more clayey and impermeable Port Durnford Beds. The soils originating from alluvium, river terraces and the Cretaceous sediments occurring in western Maputaland is fertile to very fertile (Maud 1980).

According to Matthews (2007), t three main soil types exist on the MCP. They are dystrophic regosols (Namib soil form), histosols (Champagne soil form) and humic gleysols. Dystrophic regosols are moderately- to well-leached acidic sands found on elevated places such as dune crests- and slopes. On the oldest and most westerly dunes soils are mesotrophic and profiles are generally deep, red, and well-developed, displaying advanced mineral diagenesis. The soils found in association with the easterly, younger dunes are generally poorly developed yellow to orange arenosols (Watkeys et al. 1993). Large areas of dune sand are generally classified as deep red Hutton form profiles. The soils classified as yellowish-brown Clovelly form and gray Fernwood form generally show a sharp reduction of organic matter to less than 0.5% within 30 cm of the surface (Botha & Porat 2007, Matthews et al. 1999). The low fertility regosols are derived from the Quaternary sediments and cover most of the flat to gently undulating MCP (Watkeys et al. 1993). The Histosols (Champagne form) are the acidic organic soil found in wetlands. Humic gleysols are wet acidic sand with an abnormal accumulation of organic matter and are found in depressions where a high water table occurs. Duplex soil consisting of a clay layer beneath a sandy horizon occurs in depressions, which becomes waterlogged in the wet season and sometimes forms pans. According to Matthews (2007) the wetlands occurring in the area are surface expressions of the groundwater table with few areas of perched groundwater horizons. The erosion-resistant fine-grained rhyolites of the Lebombo Range give rise to shallow lithosols. Alluvial soils occur in river systems and floodplains (Watkeys et al. 1993).

The MCP is very rich in peat resources, and contains about 60% of the estimated peat resources in South Africa (Grundling et al. 1998). This region is only the 5th largest Peat Eco-Region, but it contains the largest and highest density of peatlands of all the Peat Eco-Regions. It is estimated that 60 - 80% of these peatlands are currently being utilized by the local community for subsistence agriculture. Other uses include using material from the peatlands for thatching, weaving and braiding material (Grundling 1996). Except for two peatlands occurring in the south (the Mfabeni and Mhlanga mires), all of the peatlands in this area are younger than 7000 years (Grundling & Grobler 1995).

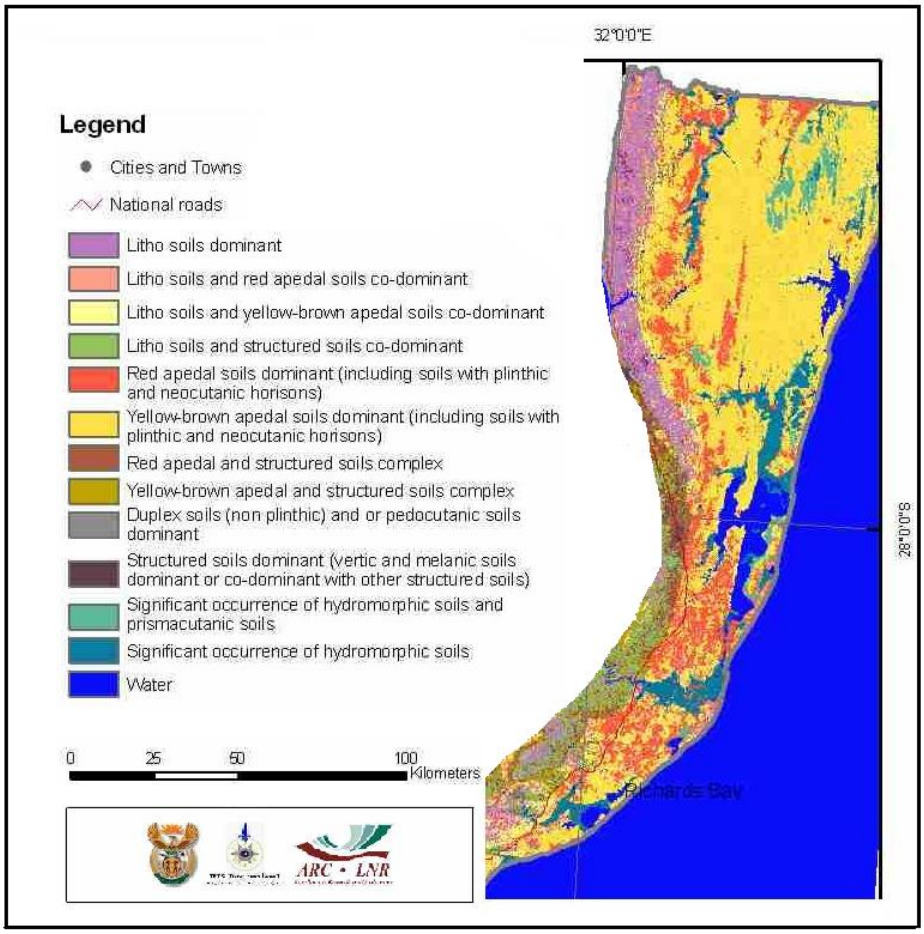

Figure 2.5. Soil associations on the MCP (Van den Berg et al. 2009).

2.7 Hydrology

The MCP consists of many different types of surface water bodies such as rivers, floodplains, estuaries, swamps, pans, and coastal lakes (Grundling 2009, Matthews et al. 1999). The longitudinal series of shallow estuaries and lakes that lie behind the narrow band of dunes separating them from the coastline boast two major estuarine linked-systems (St. Lucia and Kosi-Bay) and several freshwater water bodies (Sibaya, Banghazi North, Banghazi South and Ngobozeleni) (Briggs 2006).

2.7.1 Rivers

There are four major rivers (the uMhlathuze-, uMmfolozi-, uMkhuze-, and Pongola rivers) and three minor rivers (the Mzinene-, Hluhluwe-, and Nylazi rivers) on the MCP. These rivers (of which the iMfolozi and uMkhuze Rivers are the largest rivers with vast associated delta swamps) flow through many important wetlands and estuaries on the MCP. Many of the smaller streams in the area feed into the scattered wetlands on the MCP (Kelbe & Germishuyse 2010, Briggs 2006). The uMhlathuze flows into the Richards Bay harbour, while the uMkhuze River, together with the Mzinene, Hluhluwe, and Nylazi rivers flow into Lake St. Lucia (supplying fresh water to the system). The Pongola flows north into Maputo Bay, Mozambique. The uMfolozi swamp was once the largest fluvial plain in South Africa, but was significantly reduced through agricultural activities and the establishment of several artificial canals which reduced the floodplain during the 20th century. Where the uMkhuze

River enters Lake St Lucia, the uMkhuze Swamp is formed (Kelbe & Germishuyse 2010, Taylor et al. undated). The outflow from this swamp makes up a large part of freshwater supply to Lake St Lucia. Smaller streams in the area include the Mphate and Nkazana streams feeding Lake St Lucia, as well as the streams feeding Bhangazi North. These streams originate on the MCP. Both the Siyadla River which enters Lake Amanzimnyama (The fourth Kosi-Bay lake) and the Nswamanzi River which enters Lake kuNhlange (the third Kosi-Bay lake), originate on the MCP and feed the Kosi-Bay System. These rivers are mostly seasonal rivers which are reduced to isolated pools and subterranean seepage during winter months.

2.7.2 Estuaries

The importance of the estuarine systems on the MCP is highlighted by the study done by (Maree et al. 2003), which indicates that six of the MCP estuaries consistently lie in the top seven rankings for estuaries in terms of fish importance, and number one ranking for fish, botanical and waterbird prioritization. According to Kelbe & Germishuyse (2010), these estuaries form an imperative ecological link between the rivers and the sea, of which the regular opening and closing of the systems that create large diversity in the physical conditions of the estuaries play a vital role and are not well understood.

2.7.3 *Wetlands*

The Maputaland coastal plain is covered by many wetlands that are either fed by the various rivers and streams, or occur as an extension of the water table. The groundwater is the principal source of water for most of the wetlands in Maputaland (Grundling et al. 2014, Kelbe & Germishuyse 2010).

2.7.4 Coastal lakes

Kelbe & Germishuyse (2010) classified the lakes on the MCP into four broad categories. These are:

- the coastal inland lakes with river outflow (the Mzingazi and Cubhu lakes),
- lakes without river outflow (the Sibayi lake),
- lakes with an estuary (the St. Lucia-, Kosi-, and Nhlabane lakes), and
- the off-channel lakes found on alluvial flood plains of the uMfolozi and uMhlathuze rivers.

The Nsezi Lake is classified separately as a lake on the boundary between the coastal plain and fed by substantial inland catchment (Nseleni River).

Lake Sibaya formed as a result of the regressions and transgressions of the ocean during the Tertiary era (Hobday 1979). The mouth closed permanently and the lake became completely isolated and elevated above the sea. The water balance of Lake St. Lucia is driven by direct rainfall and river runoff from the uMkuze-, Mzinene-, Hluhluwe-, and Nyalazi Rivers. Several smaller groundwater-dependent streams feed into the lake and estuary. Lake Mzingazi in Richards Bay was formed when the link to the Richards Bay Estuary was broken several thousand years ago. Many other smaller off-channel lakes occur on the MCP. The many shallow, small pans scattered throughout the MCP are usually associated with large flood plains and do not have a strong groundwater dependency. Only a few studies of the groundwater regime of these pans have been found in the literature (Kelbe & Germishuyse 2010).

2.8 Geohydrology

The water table on the MCP is very variable, and although it is usually found between 1-6 m below surface, it may be as deep as 60 m or more below the surface. Groundwater is almost entirely replenished by rainfall, with immediate fluctuations in the groundwater table after rainfall events (Grundling 2009, Matthews et al. 1999). Various water bodies exist on the MCP. The occurrence and extent of a specific type of water-linked ecosystem in a specific area are dependent on environmental factors and processes such as topography, rainfall, water table, soil type and water retention (Grundling 2009, Matthews et al. 1999).

According to Kelbe & Germishuyse (2010) and Meyer et al. (2001), the marine, alluvial, and aeolian sediments overlying the Cretaceous sediments are hydrogeologically most significant. All the interactions between the groundwater and surface water take place in these layers. The groundwater table tends to follow the topography closely, suggesting a relatively low hydraulic permeability of the surface soils (Grundling & Grundling 2010, Meyer et al. 2001).

The rivers, lakes, and wetlands occurring on the MCP are predominantly groundwater driven. Different lithologies have different hydraulic characteristics due to, amongst others, the difference in mineral composition, grain size, porous spaces and connectivity of the soils on the MCP (Grundling & Grundling 2010). According to Colvin et al. (2007), two primary porosity aquifers characteristic of unconsolidated aquifer types are present on the MCP. The Maputaland Coastal Aquifer (MCA) consists of a shallow, unconfined aquifer (or perched water table) and a deeper, confined aquifer. The shallow, unconfined aquifer exists in areas with a rainfall higher than 800mm and is a result of the well sorted, highly porous and permeable Pleistocene and Holocene sediments and cover sands**,** while the deeper, confined aquifer of the Uloa and Mkwelane formations typically contains a large amount of groundwater. At present it is unknown how the deeper, confined aquifer is recharged (Colvin et al. 2007, Rawlins & Kelbe 1998). The shallow, unconfined aquifer is driven by rainfall events. Infiltration and permeability of the sand cover of the KwaMbonambi Formation is high and overlays the less permeable Kosi-Bay Formation. Rainfall thus infiltrates the sandy soils and percolates through the permeable KwaMbonambi Formation until it reaches the impermeable Kosi-Bay Formation. Water then moves laterally to exit the aquifer in the form of surface water sources such as lakes, streams and permanently wet wetland areas. This impervious layer is thus a crucial factor in the distribution and occurrence of many of the seasonal and permanent wetlands of the region, especially in valley-bottoms where the clay-enriched weathering profiles are exposed (Grundling & Grundling 2010, Botha & Porat 2007). The MCA is the largest primary coastal aquifer in South Africa (Meyer et al. 2001). Because the hydrology of the MCA influences ecological patterns and processes, the area can be regarded as an Aquifer Dependent Ecosystem (ADE). Aquifer Dependent Ecosystems are important indicators of aquifer health and flow regimes, as their distinctive ecohydrology makes it an important biodiversity hotspot (Colvin et al. 2007).

2.9 Vegetation

According to Matthews (2007) water table and groundwater movements play an important role in the maintenance of the vegetation types due to the deep sand deposits in most parts of the MCP. The combination of diverse ecosystems occurring in the area contributes significantly to the high level of endemism and diversity of the area. Almost all life forms and life history types are represented by the endemics of the MCP. The presence of the high number of annuals and short-lived perennials is a rare occurrence, and not easily found in other centres of endemism with summer rainfall. More than 2500 species of vascular plants are found in the area, of which 203 species and 3 genera are endemic or near-endemic to the area (Van Wyk 1994). The six families with the largest number of endemics are the Asclepiadaceae, Euphorbiaceae Rubiaceae, Lilliaceae, Acanthaceae and Asteraceae (Van Wyk & Smith 2001).

The vegetation of the MCP is remarkably diverse. The major vegetation types of the MCP on the South African side have been broadly identified and described by Moll (1978, 1980). Some vegetation types are also presented in Mucina & Rutherford (2006). The vegetation of southern Mozambique has been described by Myre (1964). Tinley (1971, 1976, and 1985) conducted some vegetation surveys along the coast. Lubbe (1996) conducted a detailed vegetation study of coastal strips from the Mozambican border to Sodwana Bay. Many detailed vegetation studies have been conducted in the officially conserved areas on the MCP. These works include the studies of Goodman (1990) in the Mkhuze Game Reserve; De Moor et al. (1977) in the Ndumo Game Reserve; Gaugris & Van Rooyen (2007) in the Tshanini Game Reserve; Matthews (2001) in the Tembe Elephant Park; and Matthews et al. (1999) in the Sileza Nature Reserve. Wetland vegetation specifically has been described by Venter (2001), Sieben (2014), and Pretorius (2014 and 2016). Sieben (2014) compiled a national wetland vegetation database that gave considerable attention to the vegetation communities, diversity, and indicator species in wetlands on the MCP under the cluster name 'Subtropical wetland vegetation'.

2.10 Biodiversity

This MCP lies in what is considered as the Maputaland Centre (Figure 2.6), one of Africa's most important biodiversity hotspots and centres of endemism (Van Wyk & Smith 2001). The Maputaland Centre of endemism is located at the southern end of the African tropics, where many plant and animal species reach the southernmost limit of their range. Although this area has always been regarded and treated as a biotic transition zone within the larger Tongaland-Pondoland Regional Mosaic, more recent boundary delineations show that the area is in fact a centre of endemism with an extremely rich biodiversity (Van Wyk & Smith 2001, Moll 1980). This unique area is made up of a mosaic of diverse ecosystems and multiple broad ecological zones such as thicket, grassland, bushveld, forest, sand forest and swamp forest, all which is defined by variations of dune ridge sequence, abrupt changes in soil catena variation, soil fertility variations, drainage and seasonal water stress, climate, rainfall anomalies, and the influence of fire (Matthews et al. 2001, Van Wyk & Smith 2001, Moll 1980). The different vegetation units and ecological zones contribute significantly to the high level of endemism and diversity of the relatively small area. Most of the flora and fauna are of Afrotropical origin. According to Van Wyk & Smith (2001), the ecosystems on the MCP might be of recent derivation. The high level of biodiversity is described by the term 'neo-endemics', and is a result of active biological speciation. Many of the Maputaland Centre endemics (especially plants and animals) appear to be recent diversification. At least 2500 vascular plant species occur in the area with more being discovered still. Of these 2500, at least 225 species or infraspecific taxa are endemic or near-endemic (Van Wyk & Smith, 2001). More than 472 bird species (almost 60% of

South Africa’s total bird population) are found in the Maputaland Centre, of which 4 species and 43 subspecies are endemic or near endemic. (Van Wyk, 1996). Species richness in mammals is also high, with 14 endemic or near-endemic species and infraspecific taxa (Van Wyk, 1996). Amphibians and reptiles are also diverse and support some endemic species (Van Wyk, 1996). Data also exist on the freshwater fishes and this is an area of some endemism for them, with a total of 67 freshwater fish species, of which 8 species are endemic or near-endemic. According to Van Wyk (1996), there are some obvious connections between the Maputaland Center and other major African floristic regions such as the Somalia-Masai/Zanzibar-Inhambane Regions, the Western Kalahari-Highveld Regional Transition Zone, and the western Zambezian Region.

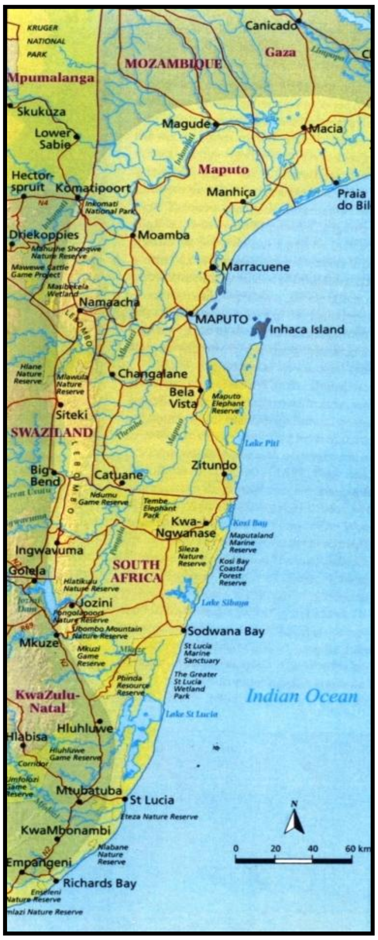

Figure 2.6. Maputaland Centre of Endemism (light shaded area) (Van Wyk & Smith 2001).

2.11 Land use and conservation

The conservation importance of Maputaland is globally recognized because of its unique and sensitive fauna and flora, active geology, and numerous heritage and RAMSAR sites. As the growing ecotourism sector is such an important part of the area, conservation is in the interest of both the environment and the local population (Watkeys et al. 1993). Maputaland contains 14 statutory Protection Areas (PAs) which are managed by the National Directorate of Conservation Areas in Mozambique, Ezemvelo KwaZulu-Natal Wildlife and the Greater St Lucia Wetland Park Authority in South Africa and the Swaziland National Trust Commission in Swaziland (Smith et al. 2008, Smith &

Leader-Williams 2006). The natural environment and wildlife of the MCP are conserved in, amongst others, the iSimangaliso Wetland Park, Ndumu Game Reserve, Tembe Elephant Park, Mkhuze Game Reserve, Phinda Resource Reserve, Sileza Nature Reserve, Usuthu Gorge Community Conservation Area, Bhekabantu Community Conservation Area, Manguzi Forest Reserve, Phongola Nature Reserve, Ubombo Mountain Reserve, Makasa Biosphere Reserve, Tshanini Game Reserve, and the Hlathikulu Forest Reserve. Only the areas of the Lebombo, the riverine vegetation types, and the coastal grasslands against the coastal dune cordon are considered underrepresented in the present conservation status. Although portions of sensitive ecosystems outside of reserves on the MCP have been impacted upon (by, amongst others, exotic *Pinus* and *Eucalyptus* plantations, the construction of the Pongolapoort Dam and large irrigation schemes on the Makatini Flats, and the clearing of land for agricultural activities), much of the vegetation of the study area is still preserved (Van Wyk & Smith 2001, Moll 1980).

The ecology and climate of Maputaland have played a large role in determining the region's present conservation status. A large portion of the land is communally owned, and due to little productive agricultural land available, local people's livelihoods depend on the harvesting of natural resources (Smith et al*.* 2008, Smith & Leader-Williams 2006). According to Smith & Leader-Williams (2006) this has led to the following situation:

• Much of Maputaland's important biodiversity remains intact, with large mammals being conserved and restricted to the PAs. However, alien invasive plant species are a serious conservation threat in many rural areas. In addition to this, most of the natural and sensitive habitats on nutrient rich soils such as wetlands are being used for subsistence agriculture;

• Most of the PAs are not large enough to contain viable populations or wide-ranging species and do not fully protect important ecological processes;

• Many of the people in the region are extremely poor;

• Modern advances have led to an increase in the extent and intensity of farming. This has serious implications for the conservation of certain sensitive habitat types;

• The human population increases and changes in infrastructure and prevailing social conditions have also increased examples of over-harvesting.

Chapter 3
LITERATURE REVIEW

3.1. Wetland delineation on the Maputaland Coastal Plain

Very few research studies focusing exclusively on wetland delineation issues exist in South Africa, of which Kotze et al. (1996), Kotze & Marneweck (1999) and Job (2009) are some. However, wetlands are mostly delineated using the guideline produced by the Department of Water Affairs and Forestry (DWAF 2005). The use of four wetland indicators is recommended, namely the terrain unit, vegetation, soil wetness, and soil form. Wetland scientists identify terrain units based on hydrogeomorphic setting. The main hydrogeomorphic (HGM) units are described in Kotze et al. (2005) and are based on Brinson (1993). The use of HGM units hypothesises that wetlands will occur in the bottom parts of the landscape, where water is expected to accumulate. The vegetation indicator may aid to find the boundary of the wetland, as plant communities undergo distinct changes in species composition along the wetness gradient (DWAF 2005). The application of this indicator is supposedly limited due to the dynamic nature of vegetation, and may therefore provide misrepresentation of the actual wetland boundaries. The vegetation composition of wetlands is discussed more thoroughly in Section 3.4.

The soil wetness indicator employs the presence and identification of redoximorphic features (such as iron and manganese) as morphological "signatures" to identify saturated and reduced conditions in soil horizons or –forms (see Section 3.3.5). The use of these features has long been established (Evans and Franzmeier 1988, Vepraskas and Wilding 1983, Veneman et al. 1976). Similarly, many technical publications make use of carbon accumulation and other carbon based morphological features to identify hydric soil (USDA-NRCS 2010), since organic carbon accumulates under saturated conditions (see Section 3.3.1). Furthermore, certain soil forms are regarded as hydromorphic soil forms (DWAF 2005, Kotze et al. 1996). Soil colour is another indicator typically used in delineation practices (USDA-NRCS 2010, Lindboa 2001, Kotze et al. 1996), although this has not been quantified by any studies. The study by Kotze et al. (1996) investigated a number of systems potentially useful for describing wetland water regimes. According to this study the use of the South African soil classification system (Soil Classification Working Group (1991)) is not necessarily recommended since it does not account for depth of waterlogging. Regardless of this, the three-class water regime scheme developed by Kotze et al. (1996) is still currently in use. The different zones (permanent, seasonal and temporary) are delineated according to the soil morphology- and form characteristics, and vegetation indicators. The Natural Resources Conservation Service (NRCS) (2009), Brady & Weil (2007), as well as DWAF (2005) recommends that the presence of hydric soils should be looked for in the top 500 mm of the soil profile.

Not all soils associated with wetlands exhibit the typical hydric soil characteristics. Many publications, especially in US literature, deal with such soil (Vepraskas & Craft 2015, Tiner 1999, Soil

Science Society of America 1997, US Army Corps of Engineers 1987). While areas with problematic wetland soil are acknowledged in South Africa, there are very few studies or research contributing data to support these statements or to suggest a solution. On sandy coastal aquifers the delineation procedure recommends the use of the following modified soil criteria (DWAF 2005):

Table 3.1. Soil criteria in the temporary zone (DWAF 2005).

Temporary zone	
Soil form: Fernwood	**Soil form: Katspruit, Kroonstad, Longlands, Wasbank, Lamotte, Westleigh, Dresden, Avalon, Pinedene, Tukulu or Dundee**
Dark topsoil (moist Munsell Value: ≤ 4; Chroma: ≤ 1)	
High topsoil SOC - variable, but usually ≥ 7%	High topsoil SOC - variable, but usually ≥ 4%
Accumulation of plant residues	Signs of wetness within 50 cm of the soil surface
Low bulk density and peaty character (often exhibits vertical profile cracking in the dry state)	Significant textural increase within 50 cm of the soil surface

The permanent and seasonal zones are similar as described in Table 3.1, but extremely high organic carbon content can be found in the top soil of these zones as a result of prolonged wetness. The organic carbon content is typically higher than 10% (Champagne soil form), and has a peaty character. The US Army Corps of Engineers Wetlands Delineation Manual (US Army Corps of Engineers 1987) describes three additional soil features that may be used as indicators of sandy hydric soils, namely high organic matter content in the surface horizon, streaking of subsurface horizons by organic matter, and organic pans. In the USA the United States Department of Agriculture & Natural Resources Conservation Service developed a list of field indicators to identify hydric soils. These are broken into three main categories based on the main substrate type (USDA-NRCS 2010). The field indicators rely on morphological features that are formed by reduction when soils are saturated.

The study by Job (2009) on the applicability of the DWAF (2005) guideline showed that in general the principles on which the DWAF guideline is based on were applicable to wetlands in the Western Cape. For the wetlands that were classified as “Specific Cases” (problematic soil) as described in the guideline, the recommended approach for delineation is:

- identify whether the site is associated with a stream or other landform or landscape position likely to support wetland,
- draw on all other wetland indicators,
- presence of a dark surface layer, high in organic carbon, even if only 2 or 3 cm thick,
- low chroma matrix, in comparison to adjacent non-wetland soils,
- site visits in the wet season,
- draw upon the expertise of an experienced soil scientist to help interpret the site.

One of the main recommendations is to interpret all the indicators present on the site, together with an interpretation of the influence of the setting and other local conditions, in comparison to adjacent non-wetland areas, so as to build an argument of whether or not an area is a wetland.

3.2. Soils on the Maputaland Coastal Plain

Since organic soil wetlands (peatlands) dominate the northern hemisphere, international literature specifically tends to focus on permanent wetland systems. There is some literature on seasonal wetlands (the prevailing wetland type in South Africa) (Day et al. 2010), but almost no literature exists on the various zones within a wetland, or the variation of soil properties on a wetness gradient.

A major distinction in hydric soil is made between organic and mineral soil (Job 2009, Reddy & DeLaune 2008, Richardson & Vepraskas 2001, Kotze et al. 1996). Organic matter accumulates in soils as a result of anaerobic conditions caused by continuous saturation, and low temperatures (Richardson & Vepraskas 2001, Kotze et al. 1996). However, organic matter can also accumulate in warm and humid areas such as the MCP, due to a high production rate of organic material in wetlands as a result of high rainfall (Job 2009, Richardson & Vepraskas 2001). Decomposition (mineralisation) is inhibited, which results in high carbon content in the soil. According to the Soil Survey Staff (1975), organic soils contain more than 18% carbon if the dominant texture of the soil is clayey and 12% carbon if the dominant texture of the soil is sandy. The South African Soil Classification System groups the organic soils into a class of their own, known as the Champagne soil form (>10% carbon, and more than 200 mm deep) (Soil Classification Working Group 1991). All other hydric soils are regarded as mineral soils. These soils have a wide range of textures, colours, base status, and pH; lower organic matter content, higher bulk density, and lower porosity than organic soils, and are periodically saturated for sufficient duration to produce chemical and physical soil properties associated with a reducing environment (Reddy & DeLaune 2008, Kotze et al. 1996). The differentiation between these two categories is important for this study, as two of the four systems presented here contain organic soil, while the other two systems are located on a mineral soil. It is also imperative to note that the wetlands containing organic soils only have high SOC levels within the first two zones of the wetland, while the outer zones consist mainly of mineral soil.

Botha and Porat (2007) provide a description of the characteristics of Maputaland soils, which are related to the terrestrial soils of the wetland sites presented in this study. The soils of the Muzi Swamp and Perched Pans (MS and PP Type) are described as loose, apedal sands commonly yellowish to pale brown (10YR 6/6-6/3; 7.5YR 6/8) with few ferruginous mottles, and 0.5 – 10% clay. The pH increases downwards in the profile. Organic matter accumulation results in distinct melanisation and acidification of the A-horizon. Both systems are indicated to exhibit clay-rich, structured, slightly saline and calcareous duplex horizons, as well as hardpan calcrete (Botha & Porat 2007, Matthews et al. 2001). According to Hobday and Orme (1974), this is due to the coastal plain wetlands surrounded by dunes rather than by a coastal barrier beach and lagoonal environment. According to Matthews et al. (2001), the permanently wet soils are characterized by gleying conditions and peat formation. The Moist Grasslands (PL Type) comprises an organic-enriched A-horizon underlain by a grey sandy subsoil with clay enriched horizons in some areas. Abrupt pH, colour and textural change are evident at 1.5 – 4 m depth. Grey clay-enriched or ferruginous mottles and lamellae may be visible. The yellowish Clovelly or grey Fernwood form soils found in areas with high water tables within low-lying interdunal depressions show a sharp reduction of organic carbon to levels of less than 0.5% within 300 mm of the surface (Matthews et al. 2001). The Interdunal Depressions are described to have colours of 7.5YR 6/8, up to 3% clay, and lower pH. It is suggested that the grey sands exhibited on the MCP is a single sand unit in which the upper bleached section is a thick eluvial horizon representing a lengthy pedogenic bleaching episode (Botha & Porat 2007).

According to Fey (2010) the leached nature of hydromorphic soils with E horizons as is found on the MCP is expected to be low in nutrients and with a low CEC and pH. This might change lower down in the profile when the usually more clayey B horizon is reached. A fluctuating water table as is found in seasonal/temporary zones may have a strong influence on nitrogen loss by denitrification. In wetlands where the G horizon is close to the surface such as in the Katspruit form, the soil can be expected to be wet throughout most of the year. The Katspruit form usually has a better reserve of plant nutrients and a higher pH, CEC, and organic matter content than soils of surrounding uplands.

3.3. The biogeochemistry of soil in wetlands

Hydrology is the main controlling factor of the physical, chemical and biological properties (i.e. biogeochemical characteristics and cycles) of wetland soil. According to Reddy and DeLaune (2008), nutrient loading is characteristically greater in wetlands than in uplands due to the topographic setting. Waterlogged soil alters chemical reactions such as pH, redox reactions, electrical conductivity, CEC, and the sorption and desorption of ions (Reddy & DeLaune 2008, Neue et al. 1997). Flooding causes a soil to become anaerobic because air moves 400 times slower through water than through soil (Collins 2005). The magnitude and intensity of soil reduction is controlled by the amount of organic matter, its rate of decomposition, and the amount and types of reducible nitrates, manganese and iron oxides, sulphate and organic substrates (Neue et al. 1997). Wetland soils can act as a sink, source, or transformer of nutrients (Reddy & DeLaune 2008). The aim of this study is not to investigate biogeochemical cycles and inter-relationships of properties in the wetland systems on the MCP and therefore only a broad overview will be given of the various soil properties and how they vary between wetland zones and –systems.

3.3.1 Soil organic carbon

Soil Organic Carbon (SOC) is the primary driver for all biogeochemical processes in wetlands (Bernal & Mitch 2008, Reddy & DeLaune 2008). SOC refers to the carbon in soils originating from the products of photosynthesis and living organisms (organic matter) and is a heterogeneous mix of simple and complex organic carbon compounds (Chan et al. 2008, Reddy et al. 2000). SOC is a dynamic component of an ecosystem, with both internal changes in the vertical and horizontal directions and external exchanges with the atmosphere and the biosphere (Zhang & McGrath 2004).

SOC accumulation in soils is a function of the carbon balance between inputs (organic matter production) and losses (decomposition) (Adhikari et al. 2009, Bernal & Mitch 2008, Schlesinger 1977). Decomposition is prevented by 1) permanent wetness, 2) low temperatures, 3) extreme acidity or lack of nutrients, and 4) high concentrations of electrolytes or organic toxins - all of which slow down microbial oxidation of the organic matter (Fey 2010). Other secondary, inter-related factors controlling decomposition in wetlands include wetland type and hydrogeomorphic setting, hydroperiod, quality, and quantity of the organic matter, microbial communities, electron acceptors supply, low redox potentials, and pH (Reddy & DeLaune 2008, Neue et al. 1997). SOC content and decomposition rates decrease with depth of a soil profile, because most organic residues are incorporated into the soil at the surface and become more recalcitrant and thus difficult to break down (Reddy & DeLaune 2008, Reddy et al. 2000). Soil organic matter is a source of and provides long-term storage for nutrients in the soil (Reddy & DeLaune 2008). SOC is generally higher in clay soils than in sandy soils due to the clay protecting the organic matter against oxidation. The smaller pores of these clayey soils also restrict aeration and reduce the rate of organic matter oxidation. In poorly drained soils, the high moisture supply promotes litter production while the poor aeration inhibits organic matter decomposition.

SOC is accumulated much more effectively in the permanent zones than in the seasonal/temporary zones of a wetland. The fluctuating water table in seasonal and temporary zones results in the oxidation of a considerable portion of the carbon that would have been retained in the soil under saturated conditions (Bernal & Mitch 2008, Phillips & Greenway 1998). Aerobic soils have minimal net retention of organic matter, and what is left consist mainly of highly resistant and stable compounds (Reddy & DeLaune 2008, DeBusk et al. 2001). Anaerobic fermentation plays an important role in the decomposition of reduced carbon, comprising the breakdown of complex substrates before oxidation. This results in an array of substances not found in well-aerated soils (Neue et al. 1997) such as various gases, hydrocarbons, alcohols, carbonyls, volatile fatty acids, nonvolatile fatty acids, phenolic acids, and volatile S compounds (Ponnamperuma 1984).

SOC improves CEC, supplies nutrients such as nitrogen and phosphorous, and affects physical properties including lowered bulk density and increased hydraulic conductivity, infiltration capacity, and water holding capacity (Passoni et al. 2009). Permanent flooding may reduce the availability of some nutrients (Neue et al. 1997). Although the dynamics between the above mentioned soil properties are infinitely complex, it can be expected that these properties will dynamically vary between zones as a result of its dependence on SOC. Because two of the four systems presented in this study are organic soils (some containing peat), a separate section is devoted to peat soils.

Peatlands

A peatlands is a very rare wetland type in South Africa (Grundling 2002). Peatlands cover only 3% of the land area worldwide, but contain 30% of the global soil carbon. The International Mire Conservation Group (IMCG) defines peatlands as wetlands with more than 30% organic matter or more than 20% organic carbon, and more than 300 mm of peat. Peat in the South African soil classification system is by default classified as a Champagne soil (Grundling 2010, Soil Classification Working Group 1991).

The sources of, and flow of water though, a peatland has a strong influence on the chemistry of the system (Charman 2002). Both the Muzi Swamp and the Interdunal Depressions in this study classify as fens (driven by groundwater, but also receiving surface runoff water from mineral soils). Fens are regarded minerogenous, because nutrient elements are added to the peatland. While the Muzi Swamp is a soligenous minerotrophic peatland (has an inlet and/or outlet), the Interdunal Depressions are a topogenous minerotrophic peatland (no inlet or outlet; Rydin & Jeglum 2008, Grundling 2002). A rich fen is usually eutrophic with a pH of 6.8 - 8 and rich in vegetation composition, while a poor fen is oligotrophic, with a pH of 4 - 5.5 (Rydin & Jeglum 2008). Peatlands receiving surface runoff from areas overlaying calcareous bedrock such as the Muzi Swamp are particularly rich in carbonates (Charman 2002). This has an effect on soil chemistry, especially redox morphology, and on plant growth.

The elementary composition of peat is strongly related to ecosystem type, peat type, and the eutrophic - oligotrophic gradient. The more minerogenous and open the ecosystem, the less efficient is its ability to trap nutrient and metals (Rydin & Jeglum 2008). The chemical regime of peatlands can be separated into two groups. Firstly the variation in pH (also strongly linked to electrical conductivity (EC) and Ca content) is highly influential in terms of the chemical character of the peatland. Secondly the variability of plant nutrients determines the chemical character, of which N is the key nutrient, but P and K is often more limiting in peatlands then in mineral soil wetlands (Rydin & Jeglum 2008, Charman 2002). Vegetation composition, physical properties, and chemical properties of peatlands are highly interrelated. High correlations have been found between vegetation composition variation and pH and mineral content (Rydin & Jeglum 2008).

3.3.2 Nitrogen

Organic matter dynamics is tightly coupled to the biogeochemical cycles of nitrogen by the processes of decomposition, mineralization and plant uptake (Chen & Twilley 1999). High nitrogen levels in the soil can increase decomposition rates and thus inhibit carbon accumulation (Lu et al. 2007.).

Nitrogen is often the most limiting nutrient in flooded soils (Bai et al. 2005, Reddy et al. 2000). As with SOC, nitrogen occurs as a complex mixture of organic and inorganic forms in any ecosystem. Nitrogen is a very mobile element and the relative proportion of each form depends on the sources of nitrogen entering the system and the relative rates and turnover times of these compounds (Rydin & Jeglum 2008, Charman 2002).

The major nitrogen inputs to wetlands are point and non-point sources (such as floodwater), precipitation, and decomposition and mineralization of organic matter. Nitrogen losses from wetlands occur as a result of plant uptake, immobilization, leaching, ammonia volatilization and denitrificaton (Reddy & DeLaune 2008, Chen & Twilley 1999). Redox reactions control a large portion of the nitrogen cycle processes. The availability of nitrogen in a wetland is therefore influenced by temperature, hydrological fluctuations, water depth, electron acceptors availability and microbial activity.

As with SOC, saturated soil conditions and a fluctuating water table have a huge influence on the dynamic cycling of these elements. Inorganic nitrogen as well as the reduction of nitrates is a function of anaerobic conditions, pH, and redox conditions. Since N_20 is released into the atmosphere as a result of reduction, nitrogen is lost from the wetland.

3.3.3 pH

The concept of pH is defined as pH = -log $[H^+]$, where $[H^+]$ is the activity of H+ ion in solution. At high pH, solutions have low H^+ activity and compounds are not protonated. pH is a very dynamic wetland soil property. It can fluctuate daily or seasonally, along with the hydroperiod of the wetland, and/or with the depth of a soil profile. It can also vary over very small distances (<5 mm). Along with SOC and nitrogen, pH is one of the most important electrochemical properties affected by saturated soil conditions (Reddy & DeLaune 2008).

A strong relationship exists between soil pH and SOC content (Reddy & DeLaune 2008, Lu 2007, Bai et al. 2005, Noordwijk 1997). The study showed that between the pH of 5 – 6 the lowest SOC content can be expected (Noordwijk 1997), although this differs from wetland system to system (Bai et al. 2005). Below a pH of 5, reduced biological activity and the increase in toxic cations may reduce the decomposition rates of organic matter. Soils with a higher organic matter content tend to have a lower pH, lower nutrient availability, and are more reduced than mineral soils. Since wetlands are usually acidic, saturated soil conditions generally increase the pH (Reddy & DeLaune 2008, Phillips & Greenway 1998). Flooded alkaline wetland soil tends to approach a neutral pH under flooded conditions. The increase of pH in acid soils depends on the activities of oxidants (nitrates, iron and manganese oxides, and sulfate) and proton consumption during reduction of these oxidants under flooded conditions. If these acid soils are low in SOC and reactive iron content, the pH is very slow to rise after flooding, but usually stabilizes after a few weeks. In alkaline soils pH is controlled by the accumulation of dissolved CO_2 and organic acids. This phenomenon implies that waterlogged soils are buffered around neutrality by substances consumed/produced during redox reactions (Reddy & DeLaune 2008). According to data published by Faulkner & Richardson (1989), pH in different wetland types usually vary between 3.9 and 6, but may go up to 8 when including freshwater wetlands located in limestone areas.

Wetland soil containing high levels of SOC result in large increases in CEC with increasing pH under saturated soil conditions. However, since the CEC of organic matter is pH dependant, subsequent decreases in pH will lead to a reduction in CEC and release the balancing cations into the soil solution (Phillips & Greenway 1998). Contradictory to this Fey (2010) reports that soils high in SOC have a low CEC due to the prevalent undecomposed organic matter. Increases in CEC of waterlogged sandy soils are quite low in comparison with other soils since sandy soils contain only small quantities of materials with variable charge. Saturated soil conditions can therefore enhance the ability of soils with variably charged colloids to retain nutrients through increases in CEC.

Soil properties and environmental variables such as temperature can significantly influence the fluctuation of pH (Reddy & DeLaune 2008). Richardson and Vepraskas (2001) states that pH can either increase or decrease organic matter decomposition rates. Salt content is a common cause of high soil pH. Visible redoximorphic features do not easily form in saturated soils with a high pH (Vepraskas 2001). SOC content was also shown to be correlated with soil clay and silt content (Noordwijk 1997).

Many peatlands are strongly acidic due to the hydrological regime, although fens tend to be less acidic than bogs (rainwater-fed; Charman 2002). Certain geological formation may override the effect of water on pH, because pH depends on the properties of soil and bedrock that the water has passed over. Rich fens often occur in areas with calcareous soil (in the field plant indicators are used to recognize levels of richness; Rydin & Jeglum 2008). The pH of the Sibaya peatlands has been shown to vary between 3.1 and 6.9. This is typical of minerotrophic peatlands with a groundwater influence (Grundling 2002). Other controls on pH include exchange of cations in the water and the release of organic acids through decay (Charman 2002).

3.3.4 Cations and CEC

Cation Exchange Capacity (CEC) is the ability of a soil to hold positively charged ions. H, K, Na, Ca, Mg, and Al and reduced Fe and Mn can be absorbed on the negatively charged soil surfaces. According to Phillips & Greenway (1998), published information on soil nutrients such as soluble and exchangeable cations and anions as well as CEC is scarce, especially for wetlands located on mineral soils.

Organic soils generally have a higher CEC, are believed to be effective 'traps' for cations, and therefore have a higher buffering capacity than mineral wetlands (see Section 3.3.1). This is because organic matter produces organic acids, lignin, carboxylic- or phenolic groups, and many other products on decomposition which exhibit exchange properties (Reddy & DeLaune 2008, Rydin & Jeglum 2008, Charman 2002). However, the few existing studies quantifying the fluxes to and from peatlands suggest that fluxes vary between cations and over time (Reddy & DeLaune 2008). A strong correlation exists between CEC and pH, as is discussed in Section 3.3.3.

According to Phillips and Greenway (1998), saturated soil conditions generally increase the concentrations of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, and NH_4^{+} in the soil solution. This may be attributed to either a loss of exchange/adsorption sites due to solubilisation of SOC, or displacement from the CEC sites due to increased concentrations of soluble Fe^{2+} and Mn^{2+}. A heightened solubility of organic matter results in an increase in water-soluble cation concentrations. However, increasing Fe^{2+} and Mn^{2+} competing ions, and the possible loss of CEC sites through their dissolution, may also lead to an increase in water-soluble cation concentrations (Phillips & Greenway 1998). Multivalent cations such as Ca^{2+} and Mg^{2+} are more easily adsorbed by organic matter than monovalent cations. Low reactivity clays often have a stronger preference for monovalent cations (Phillips et al. 1988). The high Ca concentrations in peats may induce deficiencies in elements such as $K^{+}$and Mn^{2+}.

Since a major proportion of the CEC arises from the organic carbon fraction, increase in SOC contributes to almost linear increases in soluble Ca^{2+} and Mg^{2+} concentrations (Phillips & Greenway 1998, Wolt 1994). Larson et al. (1991) found that the increase in availability of cations such as NH_4^{+} Ca^{2+}, Mg^{2+}, K^{+}, Fe^{2+}, and Mn^{2+} in the solution phase under saturated soil conditions is especially visible in calcareous wetlands. Potassium has variable patterns in peatlands, although it tends to be highest at the surface. According to Rydin & Jeglum (2008), this is due to nutrient cycling and -conservation in the living portion of peatlands, and also due to the leaching of K from subsurface layers as humification progresses. Proctor (1992) indicates that Na^{+} and Mg^{2+} ions varied with distance from coast. Generally, an increase in saturated soil conditions results in an increase of resistance (Reddy & DeLaune 2008). Resistance was measured in this specific study to examine whether distance from the sea influenced the salt content in the soils.

3.3.5 Iron and Manganese

When saturated soil conditions prevail, anaerobic conditions will result in the reduction of Fe^{3+} and Mn^{4+} oxides to form reduced Fe^{2+} and Mn^{2+}, resulting in the accumulation thereof in soil pore water. The cation exchange sites are now dominated by Fe^{2+} and Mn^{2+} which displaced the base cations such as Ca^{2+} and Mg^{2+}. The reduced cations are transported with moving water or along a concentration gradient until an aerobic zone are reached, causing these cations to precipitate again. These ‘mottles’, or redoximorphic accumulations, are an invaluable tool in the determination of the hydrology of wetlands. Reduced Fe^{2+} and Mn^{2+} act as reducing agents which, upon donating electrons, are oxidised. Wetlands usually have abundant electron donors, and limited electron acceptors, while non-wetland soils tend to be the opposite (Reddy & DeLaune 2008). Oxidised Fe and Mn provide colour, are insoluble, and immobile in soil, while reduced Fe^{2+} and Mn^{2+} are colourless, soluble, and mobile.

The ions Fe^{2+} and Mn^{2+} (and subsequent redox reactions) are important in the decomposition of organic matter, nutrient regeneration, are involved in nutrient release in flooded soils, and may decrease the availability of certain plant nutrients through precipitation. Excessive amounts of these nutrients may have an adverse effect on plant growth. It can suppress other microbial processes that regulate organic matter breakdown, alter pH, oxidize toxic organic contaminants and cause mottling and gleying. The stability of Fe and Mn phases in a wetland is regulated by pH and redox potential. A low pH increases the water solubility and exchangeable pool of Fe. Regulators of Fe and Mn reduction include electron donors (organic matter) quality and quantity, bioavailability of Fe and Mn minerals, and soil pH and temperature. Fe and Mn are important electron acceptors, especially in mineral wetland soils (Reddy & DeLaune 2008).

3.4. Wetland vegetation

3.4.1 Plants as indicators

The most visible aspect of the wetland environment is the vegetation, which also plays an important role in the functioning of wetlands (Cronk & Fennesey 2001). Wetland plants are adapted to survive under conditions that are, at least for part of the year, anaerobic and affected by the altered soil chemistry. Wetland plants may be floating or submerged, although most are emergent (the largest part of their shoots emerges above the water surface like sedges and grasses) (Cronk & Fennessy 2001, Cook 2004). Wetland environments are harsh environments for plants to grow in, due to fluctuating water levels, the frequency and duration of flooding, mobilization of toxic elements, acidity, and access to resources such as light, water, oxygen, and nutrients (Collins 2005, Charman 2002). Wetlands plants exhibit numerous physiological and morphological adaptations that enable them to survive in a saturated environment, with some more ably adapted than others. Physiological adaptations include oxidized rhizospheres, germination flexibility, accelerated stem growth, C4 photosynthesis, alternate metabolic pathways, and nutrient conservation. Morphological adaptations refer to the plant’s use of aerenchyma, lenticels, hollow stems, pneumatophores, and shallow and adventitious roots (Reddy & DeLaune 2008, Rydin & Jeglum 2008, Cronk & Fennessy 2001). There is a variety of conditions and processes that affects the types, distribution and productivity of plants in wetlands. Wetland hydrological cycles govern many factors responsible for plant species composition (Reddy & DeLaune 2008). It is possible to draw many conclusions about ecological conditions by investigating plant community composition (Bredenkamp & Brown 2001).

3.4.2 Weighted Averaging

Permanently wet wetland systems (or typically the permanently wet zone within a system) are characteristically dominated by hydrophytic plant species. According to Tiner (1999), a hydrophyte is defined as “an individual plant adapted for life in water or periodically flooded and/or saturated soils (hydric soils) and growing in wetlands and deepwater habitats…". The definition goes further to emphasize that not all individuals of a species have to occur within waterlogged conditions to be regarded as hydrophytic. Wetlands are “transitional” ecosystems, and it is therefore to be expected that some species are adapted to survive on a gradient of wetness (DWAF 2005, Tiner 1999). Similarly, Sieben (2014) states that changes in environmental conditions result in shifts in plant community composition, which allows the use of certain plant species as indicators as a result of their different tolerance to environmental conditions. However, many publications argue that emphasis should rather be placed on the group of species that acts as indicators, rather than on individual indicator species (Day et al. 2010, Rydin & Jeglum 2008, DWAF 2005).

According to Scott et al. (1989) wetland community designation using weighted averages agrees well with classification of wetland habitats. A vegetation index can be developed to evaluate the response of a plant community to an environmental gradient. In wetlands the wetland indicator status of species (determined by the frequency of occurrence of plant species in wetlands) can be used in addition with species abundance or cover to produce a measure of the likelihood that an area is a wetland (Tiner 1999). Michener (1983) was the first to propose such a wetland site index, using the U.S. Fish and Wildlife Services’ regional wetland plant lists. Thereafter many studies using similar indices were conducted (Scott et al. 1989, Carter et al. 1988, Eicher 1988, Wentworth et al. 1988). The use of weighted averaging to develop indices for plots, sites, or relevés are especially used in studies where a change in the environment is studied, such as restored or created wetlands (Balcombe et al. 2005, Brown & Bedford 1997, Stromberg 1996, Atkinson 1993). Kotze & Marneweck (1999) suggested a similar prevalence index, and DWAF (2005) also suggests a similar procedure, although also cautions that the utilization hereof is time-consuming and require expert knowledge.

Plant species occurring in or close to wetlands are categorised according to their preferred habitat. These categories were first defined by the US Fish & Wildlife Service (Reed 1988) as:

Table 3.2. Plant indicator Status Categories (Reed 1988).

OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found in wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region but occurs almost always (estimated probability >99%) under natural conditions in non-wetlands in the region

specified. If a species does not occur in wetlands in any region it is not on the National Lists.

A positive (+) or negative (-) sign is used with the Facultative indicator category to specifically define the regional frequency of occurrence in wetlands. The positive sign indicates a frequency toward the higher end of the category (more frequently found in wetlands), and a negative sign indicates a frequency toward the lower end of the category (less frequently found in wetlands) (Hoare 2007).

Day et al. (2010) compiled a list of existing literature and publications regarding the distribution and/or habitat types of wetland plants in different regions of South Africa. These publications are aimed primarily at the provision of a list of wetland plants that can be used as indicator species of general wetland conditions. In order to apply the categories of Reed (1998), a list of plant species which have been assigned an indicator status is required. Most studies in the US use the 'National list of plant species that occur in wetlands' of Reed (1988). For this study the 'Annotated checklist of the wetland flora of southern Africa' (Glen unpublished) was used, as it proved to be the most exhaustive. In this publication Glen (undated) adapted the criteria of Reed (1988) (Table 3.3).

Table 3.3. Plant indicator Status Categories (Glen Undated).

Wetland Indicator Status	% Probability of occurring in a wetland	Occurrence within a wetland
Obligate wetland plant	> 99%	Always found in a wetland, adapted in various ways to live in or on the water.
Facultative wetland plant +	65–98%	Predominately present in a wetland, especially in seasonally wet areas. Occasionally found away from wetlands and can survive growing in dry areas e.g. Zantedeschia aethiopica very common in seasonal wetlands but frequently cultivated in gardens.
Facultative wetland plant	50–64%	Plants that prefer damp to wet habitats, not continuous inundation. Good indicators of high water tables and outer limits of a wetland.
Facultative wetland plant –	25–49%	Common terrestrial plants that prefer a reasonably moist habitat that occurs around the extreme, outer limits of a wetland.
Opportunistic plant	1–24%	Often ruderals that make use of the higher water table, referred to as 'Upland' in Cronk & Fennessy (2001).

Apart from the different percentages of probability of plants occurring in a wetland, the main difference from the Reed (1988) categories is that Glen (Unpublished) defines category 5 as 'Opportunistic plant' which refers to ruderal species that may or may not occur in wetlands.

These wetland indicator categories should not be taken to represent degree of wetness. An obligate wetland plant requires saturated soil or open water in order to complete certain parts of its life cycle, but this does not necessarily mean that it needs permanent saturation. Although many obligate wetland species occur in permanently flooded wetlands, they may also occur in seasonal wetlands which have saturated or flooded conditions for only a certain period per year (Reed 1988).

3.4.3 The relationship between soil properties and vegetation

As a result of the anaerobic conditions dominating wetlands, many elements are reduced (Cronk & Fennessy 2001), and this has an effect on the vegetation composition. The reduction of other elements can change the availability of essential plant nutrients such as P, K, Mg, Ca, making these elements more available to plants. Cations that becomes toxic under high concentrations such as Cu, Zn, and Mn also become more available. Plants in nutrient-poor wetlands such as peatlands are usually limited by nutrients such as N, K, and P. Such wetlands also tend to be acidic, which excludes many plant species and also influences the availability of certain plant nutrients.

A plant community is defined as an "assemblage of plant species with a relatively uniform physiognomy or appearance, and occurs in a relatively consistent type of physical environment" (Bothma 1996). Certain plant species show a definite affinity or association with each other and their environment, and can be expected to be found together in certain areas with more certainty than other species (Kent & Coker 1992). These vegetation communities can either be distinctly demarcated, or form along a gradual environmental gradient (Bredenkamp & Brown 2001). In terrestrial ecology vegetation communities tend to be large, and are influenced by environmental factors such as light, soil nutrients, slope, rainfall, and temperature which vary from area to area (Kent & Coker 1992). In specialized ecological niches such as wetlands, the drivers of the ecology of the system operate on a much smaller scale. These systems are often more sensitive, and in the case of wetland systems, very dynamic. Charman (2002) describes four main environmental gradients in wetlands, specifically in peatlands. These are:

- The acid/base (minerotrophic-ombrotrophic) gradient,
- The fertility gradient,
- The water-table gradient,
- Deep-peat-to-mineral-soil gradient.

The use of multivariate analysis in vegetation ecology provides effective ways to summarize and communicate the general patterns in vegetation data. This has the potential to facilitate the understanding of the factors that influence ecological systems, and also facilitates the differentiation of important and strong patterns from less influential ones (Legendre & Legendre 2012). Although many vegetation studies have been done on the MCP, few studies have focused exclusively on wetland vegetation composition (Pretorius 2014). Amongst these Baartman (1997) listed the plant species in selected peatlands on the MCP, Venter (2003) detailed the vegetation composition of the Mfabeni Mire in the iSimangaliso Wetland Park, and Grobler (2011) investigated the phytosociology of peat swamp forests of the Kosi Bay Lake System. More recently Sieben (2014) compiled a national wetland vegetation database that gave considerable attention to the vegetation communities, diversity, and indicator species in wetlands on the MCP.

Pretorius (2011) conducted a phytosociological classification of wetland vegetation from the five wetland types describing the vegetation composition patterns. The main conclusions were that the major determinants of the vegetation communities in wetlands on the MCP are the substrate type and (inferred) hydrological regime; and that different plant species assemblages are characteristic for the various wetland types and -zones.

The identification of characteristic or indicator species is a standard practice activity in ecology (Dufrêne & Legendre 1997), with the first use thereof already performed at the beginning of the previous century (Hall and Grinnell 1919). Indicator species can be used as ecological indicators of community types, habitat conditions, or environmental changes due to their specific environmental preferences (De Cáceres et al. 2010). Dufrêne & Legendre (1997) were the first to develop an Indicator Species Analysis as a statistical method to determine statistical indicators that express species' indicator value (IV) for a particular group. These are determined using an analysis of the relationship between the observed species presence–absence or abundance values in a set of sampled sites and a classification of the same sites (Dufrêne and Legendre 1997). When more than two groups are defined, the IV for a particular species in a particular group is dependent on the set of sample units belonging to other groups; i.e. if an indicator species in a particular group is 'perfect', it should always be present in that group and never be present in any other group. The statistical significance of the maximum indicator value recorded for a given species is tested by means of a Monte Carlo permutation procedure. The null hypothesis is that IVmax is no larger than would be expected by chance (meaning that the species has no indicator value). The applications of indicator species analysis include conservation, land management, landscape mapping, or design of natural reserves (De Cáceres et al. 2010).

3.5. The relationship between soil organic carbon and soil colour

There are a few factors which influence the colour of a soil. Firstly, the dark colours of soil organic matter influence soil colour. The various stages of organic matter breakdown impart a spectrum of dark colours to the soil, and tend to darken and mask the brighter colours from other compounds. Dark soils typically have chemical, physical, and biological conditions superior to those of light soils (Schulze et al. 1993). Secondly, moisture content influences soil colour by darkening it as the soil changes from dry to moist. The quantity of water also influences the amount of oxygen in the soil, which determines the oxidation state of a number of soil constituents such as iron and manganese. Under conditions of air and moisture, iron forms a yellow oxide imparting a yellow colour to the soil. Where soils are well drained or under dry conditions, iron forms red oxides imparting a red colour to the soil. Poorly drained soils are often dominated by blue-, green-, and greyish colours with mottling (Fletcher & Veneman 2007). Thirdly, the presence, abundance, and oxidation states of iron and manganese oxides also impact on soil colour. Red, yellow, grey and bluish-grey colours result from iron in various forms. Grey colours are mainly caused by a lack of iron oxides; yellowish brown colour due mostly to goethite; and the reddish colour to hematite. Gley (greenish or bluish) colours may be due to the green rust mineral or to reduced iron containing layer silicate minerals (Fletcher & Veneman 2007). Lastly, constituents from the parent material can also give colour to the soil. Carbonate minerals from parent material such as limestone can give soil a whitish colour; and soil low in calcium and organic matter can be pale, while high calcium or sodium content will form dark colours even with small quantities of organic matter (Senjobi et al. 2013). It has already been reported in 1967 by Majilis (1967) that soil colour is a function of iron, organic matter, pH, and soil texture.

The relationship between SOC and soil colour as suggested by the literature is not necessarily direct. Factors such as texture class, land use, size of geographic area, and climatic region appears to have an influence on whether there is a relationship between SOC and colour, and how significant this relationship is (Wills et al. 2007, Spielvogel et al. 2004, Konen, et al. 2003, Schulze, et al. 1993, Franzmeier 1988, Fernandez, et al. 1988, Renger et al. 1987, Steinhardt & Franzmeier 1979, Brown & O'Neal, 1923). Konen et al. (2003) reviewed the history of the attempts to correlate SOC and soil colour from 1923 until the early 2000s. Brown & O'Neal (1923) state that large amounts of organic carbon only seem to modify the colour of soils in certain cases. Steinhardt & Franzmeier (1979) developed a technique to estimate organic matter for cultivated silt loam textured soil in Indiana from colour. The study highlights that this specific relationship does not hold from one climatic region to another and also should be within a soil texture class and land use. Franzmeier (1988) developed a number of equations which correlate organic matter with Munsell colour Value and Chroma, and obtained an r^2 value ranging between 0.31 and 0.47. Texture was taken into account, with SOC increasing with finer texture for a given colour. The study states that soils with a low percentage of SOC can be as dark as 10YR 2/1, and that more SOC does not result in darker colours. Due to the low specific surface area, coarse-textured soils require less organic matter to look dark than do fine-textured, high specific surface area soils. Fernandez et al. (1988) showed that there is a very close relationship between Munsell Value and organic matter content in a toposequence of soils (most of which had silt loam textures). The authors specifically indicate that organic matter concentrations are more predictable within a given landscape. Schulze et al. (1993) concluded that the relationship between Munsell Value and organic matter content was poor for soils over a wide geographical area, but was predictable ($r^2 > 0.9$) within soil landscapes with similar soil textures and parent materials; and was linear within silty and loamy textured soils and curvilinear within sandy-textured soils. Konen et al. (2003) found that in north-central Iowa the combination of Munsell Chroma and Value appeared to be a good predictor of SOC concentrations with an r^2 value of 0.68 and 0.77 for wet and dry soil respectively. For Munsell Value the study found an r^2 value of 0.77 and 0.74 for wet and dry respectively. Both are logarithmic trends. The study indicates that unique relationships exist for different soil landscapes as local mineralogical, texture, and SOC composition likely causes differences in soil colour parameters. Wills et al. (2007) found that although there is a correlation between SOC and colour, predictions can be improved by separating samples by land use. Ibarra et al. (1995) found a SOC-colour parameter with an r^2 value ranging between 0.01 – 0.53. The study found that when reflectance is measured and incorporated into the indices with Munsell Value and Chroma the accurateness of the predictions increases significantly. Lindbo et al. (1998) report a r^2 of 0.63 for dry Munsell Value and SOC content and noted that Hue did not give any significant results. Fernandez & Schulze (1987) determined that the relationship between organic matter and colour is very poor. The study by Renger et al. (1987) is the only study that tried incorporating pH in the correlation between SOC and soil colour, and reported an r^2 value ranging between 0.03 and 0.18.

Apart from a visual quantification of soil colour, other methods such as remote sensing, reflectance spectra, spectrophotometric measurements, and the use of digital cameras, scanners, and image processing software can also be used to correlate colour and SOC. Other methods of colour description include RGB, decorrelated RGB (DRGB), CIE XYZ, CIE Yxy, CIELAB, CIELUV, CIELHC, and Helmoltz chromaticity coordinates (Melville & Atkinson, 1985; Viscarra Rossel et al., 2006). The choice of colour model to use for colour descriptions depends on the purpose of the study. Viscarra Rossel et al. (2006) argue that the Munsell HVC system is only appropriate for descriptive purposes, while models that use Cartesian-type coordinate systems will be more suitable for quantitative, numerical, or predictive analysis. Due to the wide use of the Munsell system when in the field, however, this is the chosen method in this study.

The relationship between soil colour and other soil parameters such as soil hydrology and iron content have been studied as well (Torrent et al. 1983, Blavet et al. 2002, Van Huyssteen et al. 2005, O'Donnell et al. 2010, Torrent & Baron, 2003). According to Van Huyssteen et al. (1997), the main challenge, when attempting to use colour in mathematical equations, is to present colour differences in some numerical format. This study developed a number of indices with a variety of combinations of Value, Hue, and Chroma. Mokma & Cremeens (1991) studied the relationship between soil colour patterns, depth and duration of water tables, and developed a horizon colour index based on matrix colour, size and colour of mottles, and continuity and colour of clay films. They found a good correlation (r^2 = 0.76) with duration of water saturation. Evans & Franzmeier (1988) developed two colour indices, and found correlation coefficients between R^2 = 0.38 and 0.85, depending on the depth of the soil horizon and the temperature during saturation.

Chapter 4
METHODS

4.1 Site selection and stratification

Many different wetland types occur on the MCP, including floodplains, peatlands, pans, depression wetlands, swamp forests, coastal lakes, and estuaries (Grundling 2009, Matthews et al. 1999, Watkeys et al. 1993). Wetland areas occurring between the Tembe Elephant Park (TEP) and Lake Nhlange at Kosi Bay were identified by means of Google Earth and available literature. The findings of this desktop study were verified by a field visit to the area during 2009. Five types of palustrine wetland types were identified (Figure 4.1). These wetland types were selected from a transect between the Tembe Elephant Park and the Kosi-Bay lakes. Grundling (2014) assembled a profile with rainfall, elevation, water table, and generalized geology for this transect (Figure 4.2) from which the five wetland types were identified.

- The Muzi Swamp (MS Type);
- The Tembe Park Perched Pans (PP Type);
- The Utilized Perched Pans (DP Type);
- The Moist Grassland (PL Type); and
- The Interdunal Depressions (IDD Type)

The wetland types are abbreviated in the abovementioned manner throughout this document.

Three transects in each of the five wetland systems were selected during a reconnaissance field visit in December 2009. The transects were selected and sampled in such a way as to be repetitions of each other. They were stratified into positions on the topographical gradient ('zones') from the upland area downwards into the wetland, based on geomorphological setting and distinct vegetation changes down the slope. Depending on the wetland type, three to five of these zones were identified in each wetland. These zones were termed Zone 1, Zone 2, Zone 3, etc; where Zone 1 was always in the centre position of the wetland, and the last zone always on the upland position. The identifier specific to each site sampled is thus indicated as, for example, MS2-04; which would refer to the Muzi Swamp, transect 2, zone 4 (Table 4.1).

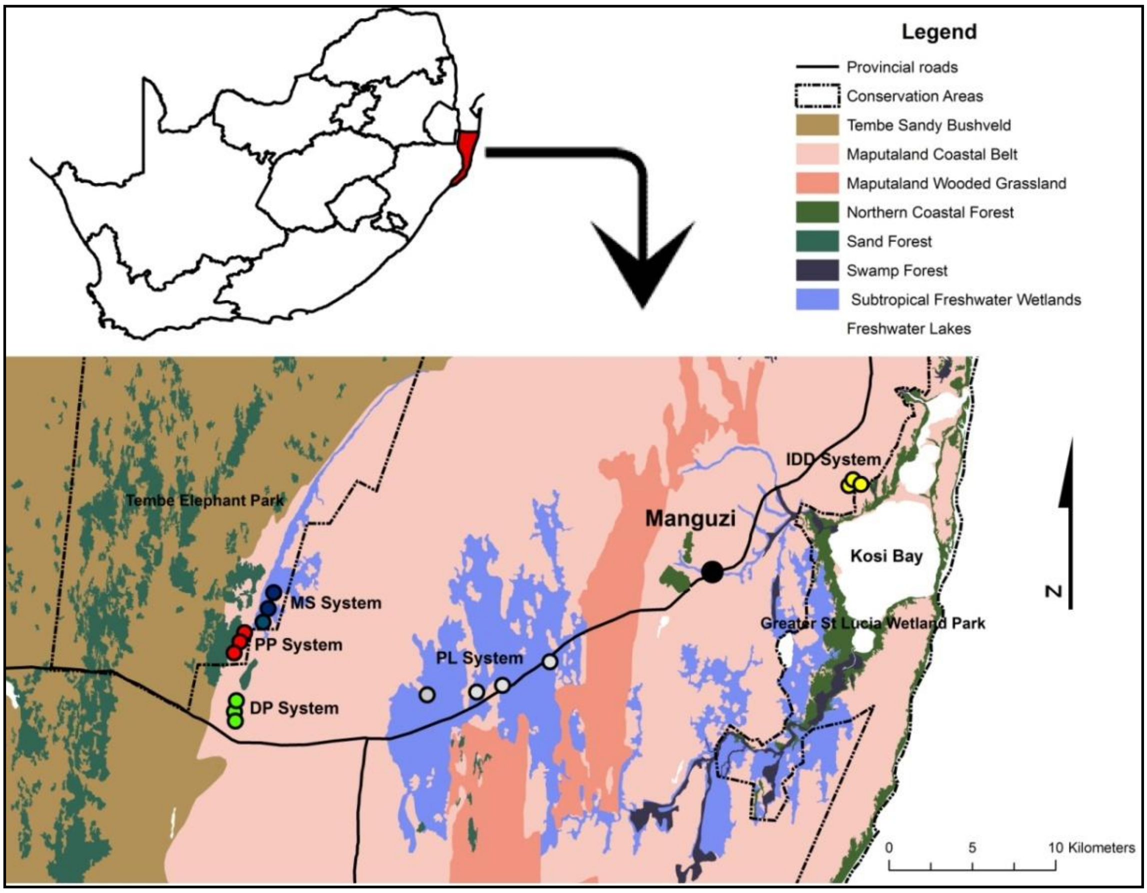

Figure 4.1. The location of the five wetland types investigated for this study within their respective vegetation types.

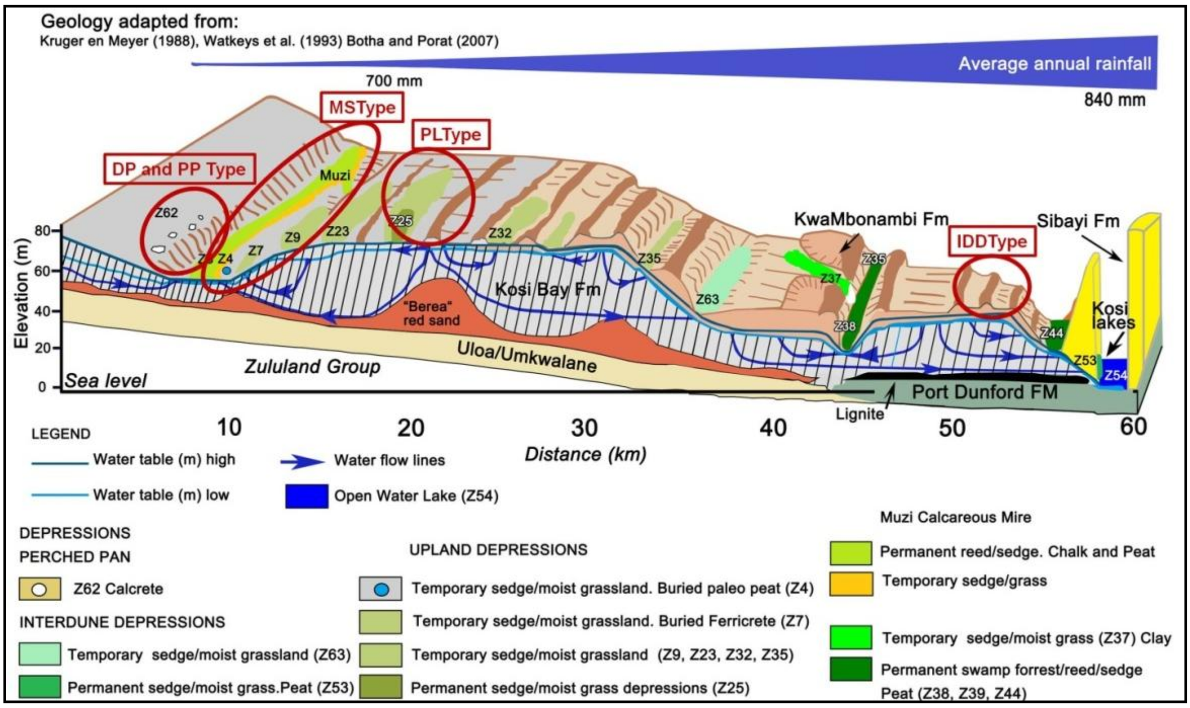

Figure 4.2. Grundling (2014) depicts a profile of the transect from the Tembe Elephant Park in the west to the shoreline in the east showing rainfall, elevation, water table, and generalized geology. Here it is adapted to show the wetland types investigated in this study.

Table 4.1. Wetland types, amount of zones sampled, and the method of sampling.

Wetland Type	Transects	Number of zones	Method of soil sampling
Muzi Swamp (MS Type)	1	4	Profile pit
	2	4	Auger
	3	4	Auger
Tembe Park Perched Pans (PP Type)	1	3	Auger
	2	3	Auger
	3	3	Profile pit
Utilised Perched Pans (DP Type)	1	4	Auger
	2	5	Profile pit
	3	2	Auger
Moist Grasslands (PL Type)	1	4	Auger
	2	4	Auger
	3	3	Auger

	4	3	Profile pit
Interdunal Depressions (IDD Type)	1	4	Auger
	2	4	Auger
	3	4	Profile pit

4.1.1 Muzi Swamp (MS Type)

The Muzi Swamp is a long, linear, north-flowing, valley-bottom system, of which a section runs through the western parts of the TEP. The MS Type is a source of groundwater discharge from the regional water table. This groundwater discharge results in peaty and organic-rich soils development in the permanently wet areas of the system. According to Grundling (2014), the MS system occurs on the Kosi-Bay Formation. This results in clay lenses occurring at about 300 – 500mm depth on the banks of the MS System (underlying the aeolian cover sands), resulting in a duplex soil. In addition to this the Muzi system is regarded as a "chalk mire" due to the occurrence of calcrete outcrops in the area and the resultant high levels of calcium carbonate content (Grundling 2002, Matthews et al. 2001). The MS wetland type is thus a system quite different from the other systems on the MCP. Sampling was done along three transects (i.e. 'wetland' repetitions) within this one wetland (Figure 4.3). The central portion of the Muzi Swamp is a mosaic of plant communities and localized elevations (probably due to, amongst others, animal trampling and water flow dynamics). Although certain plant species occur in dominant stands, the central zone as a whole is not characterized by dominant vegetation composition. The transects were chosen in such a manner to ensure that each zone of the wetland is sampled only once, which is also the motivation why the transects do not run throughout the whole of the wetland system, but typically only halfway. Two 'wet' zones consisting of a peat substrate and two typically drier zones were identified and sampled in each transect (Figure 4.3 and Figure 4.4).

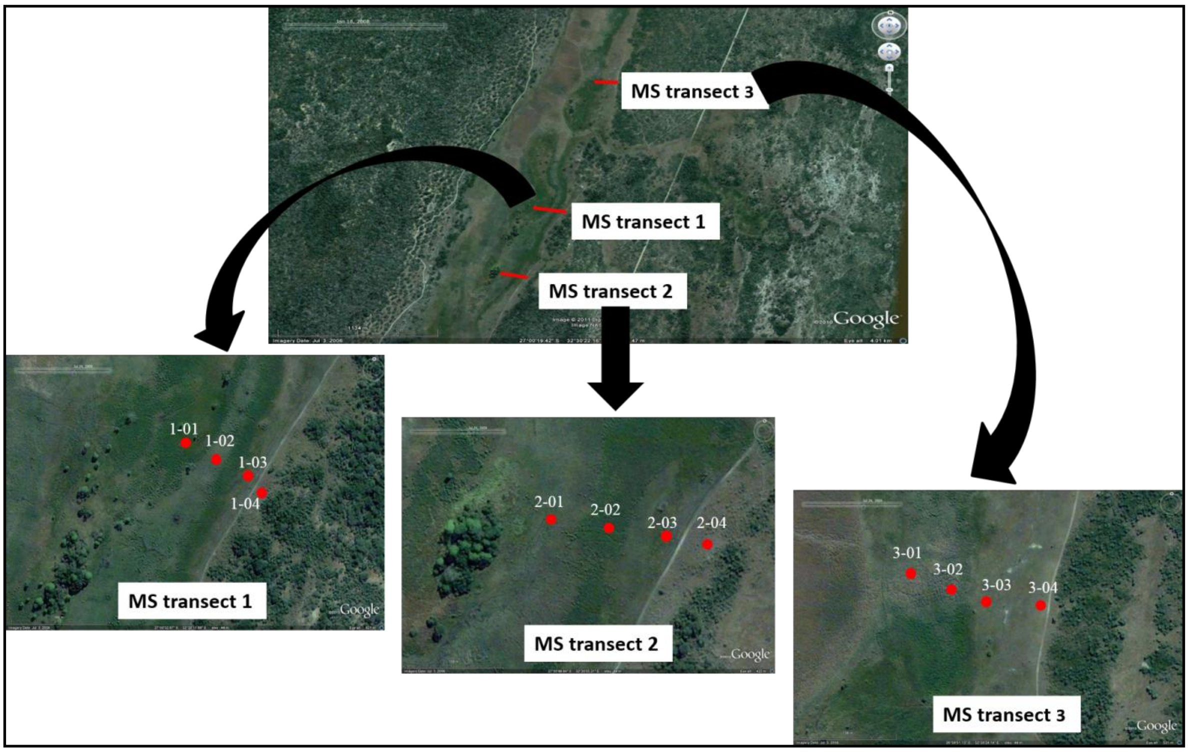

Figure 4.3. The Muzi Swamp transects.

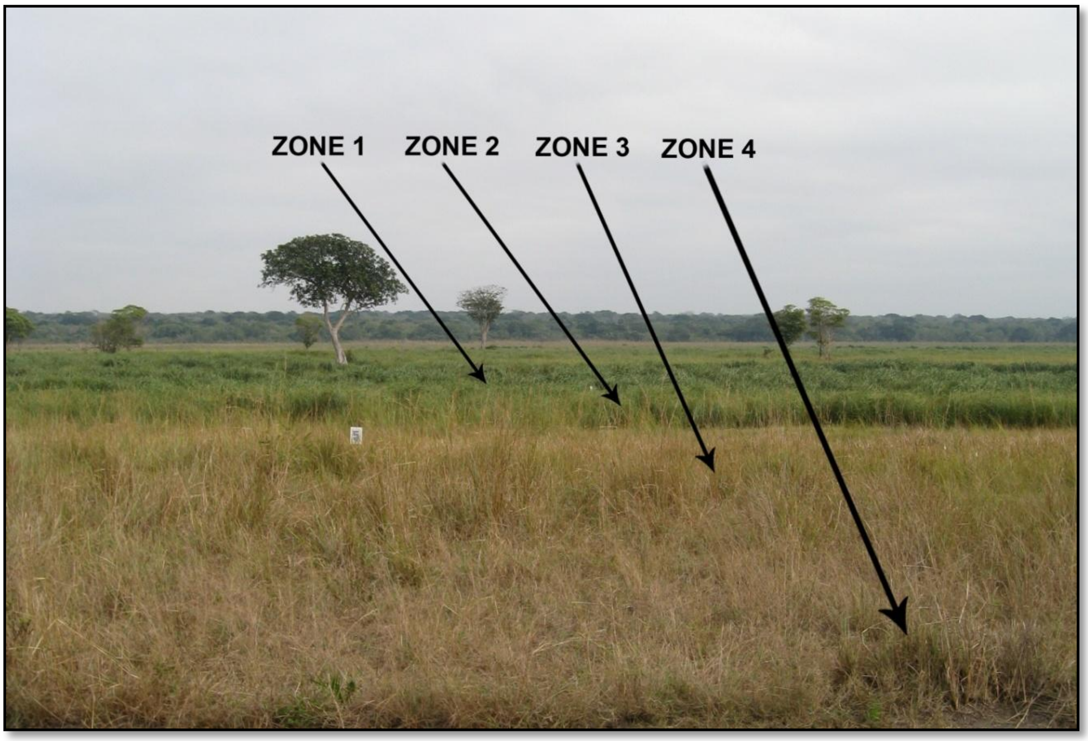

Figure 4.4. An example of the Muzi Swamp transects (Pretorius 2011).

4.1.2 The Tembe Park Perched Pans (PP Type)

The PP Type consists of a series of circular, seasonal pans occurring parallel to the Muzi Swamp System (Figure 4.5). The PP Type occurs within the Tembe Elephant Park and comprises pans surrounded by closed woodland. The PP Type occurs on the Kosi-Bay Formation (Grundling et al. 2014). These pans are not linked with the regional water table, and are exclusively replenished by rainwater and some surface run-off (Matthews et al. 2001). Lateral ground water movement towards these depressions in the area results in the formation of clay-rich, slightly saline or calcareous duplex soil in low-lying sites such as the pans. High clay content in the soil results in a perched water table for several months per year, usually October to March (Matthews et al. 2001). Three zones on the topographical gradient were identified: a seasonally wet central zone, a transition zone surrounding the central zone, and a terrestrial zone in the surrounding forested areas (Figure 4.6). These pans are utilised for supplying drinking water to animals in the TEP, resulting in obvious trampling of the central zone, especially in the drier months of the year.

The PP and DP types probably form part of a single system. Pretorius et al. (2014) hypothesised that the PP Type and the DP Type is in fact one and the same type, with the differences between the types being attributed to anthropological influence. However, these pans were found to be quite different from each other from a vegetation point of view, and were thus kept as two separate types in this study.

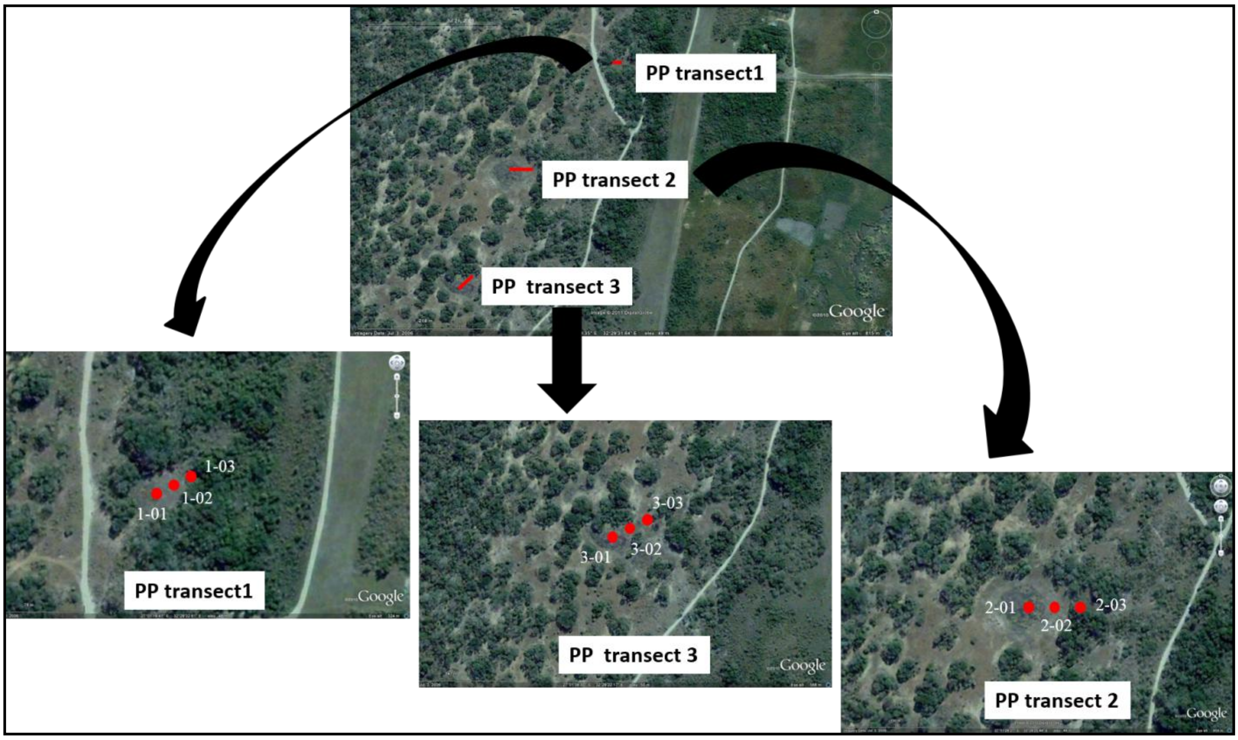

Figure 4.5. The Tembe Park Perched Pans (PP Type) transects.

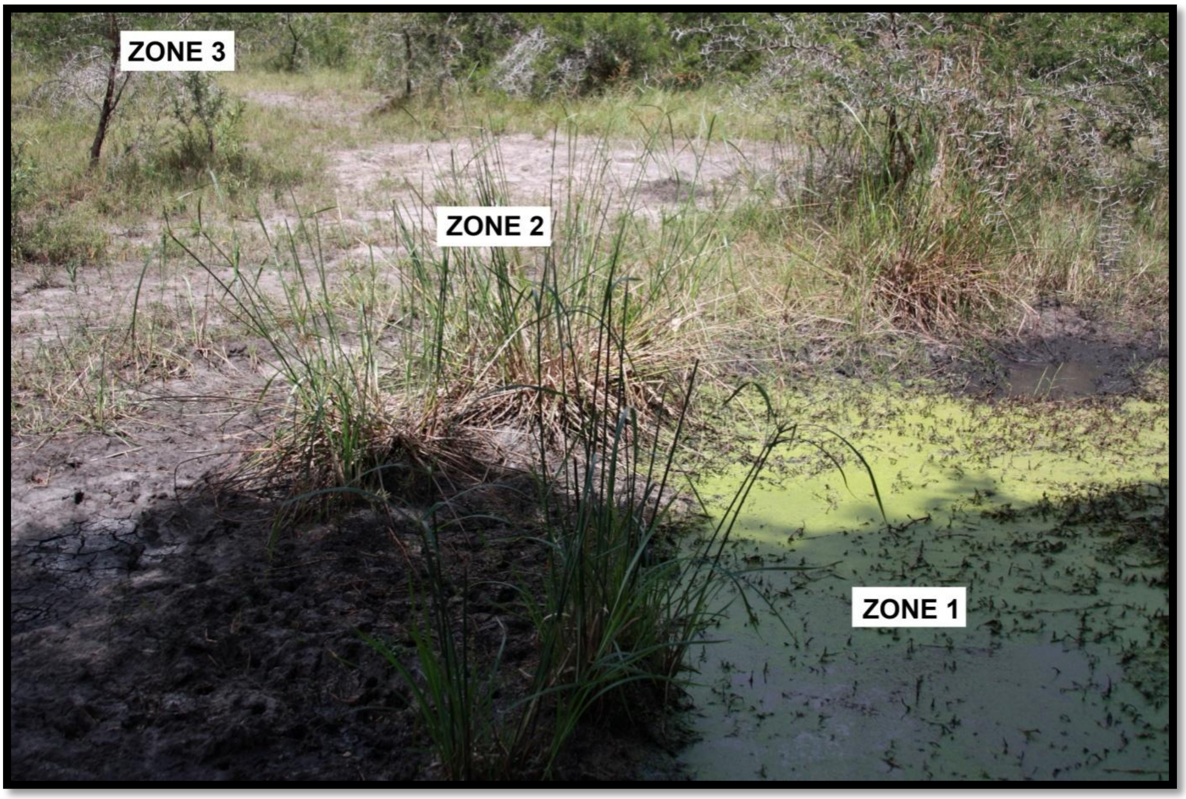

Figure 4.6. An example of the Tembe Park Perched Pans (PP Type) transects (Pretorius 2011).

4.1.3 The Utilised Perched Pans (DP Type)

The DP Type (Figure 4.7) is seemingly similar to the PP Type, except that it occurs outside the Tembe Elephant Park more to the south, and is much more impacted upon by anthropological activities (not being in a conservation area). It comprises pans surrounded by open, degraded grasslands (as a result of the area being burnt, vegetation cleared, and utilized for water and grazing). As with the PP Type the DP Type occurs on the Kosi-Bay Formation (Grundling et al. 2014), and not linked with the regional water table. It is has also clay-rich, calcareous duplex soil in the pans. Three to five zones were identified on the topographical gradient (Figure 4.8). The three pans selected for sampling varied somewhat in size – resulting in the different amount of zones sampled in the pans.

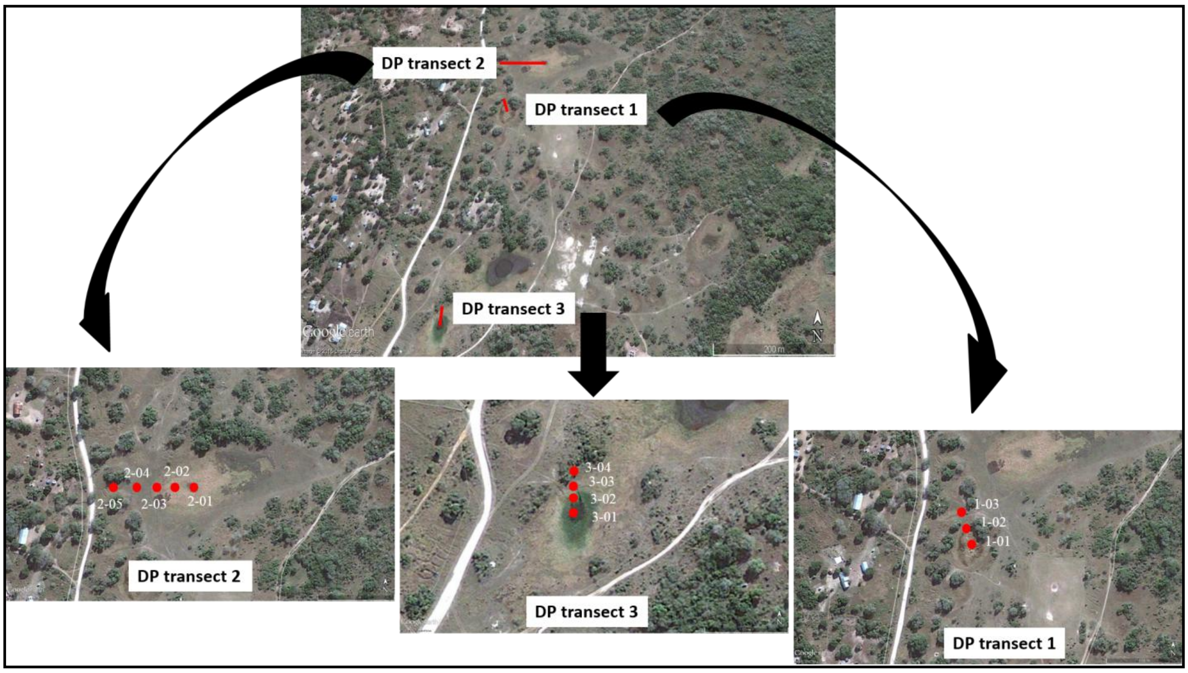

Figure 4.7. The Utilised Park Perched Pans (DP Type) transects.

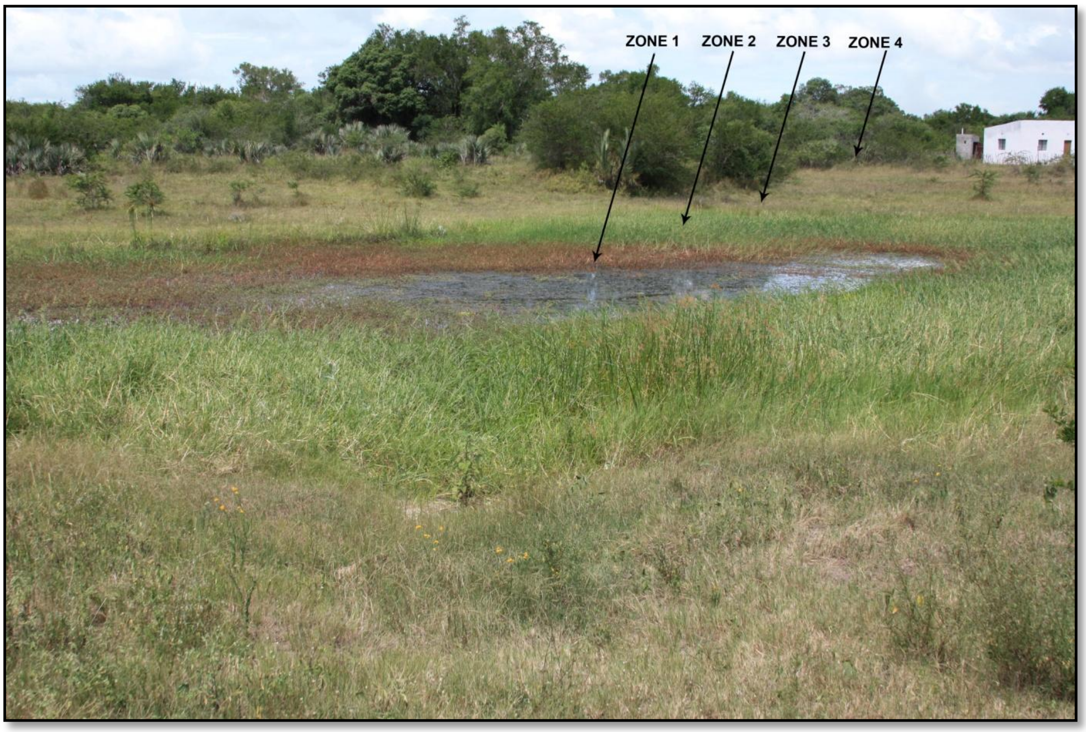

Figure 4.8. An example of the Utilised Perched Pans (DP Type) transects (Pretorius 2011).

4.1.4 Moist Grasslands (PL Type)

The Moist Grasslands wetland system is a flat, seasonally flooded system occurring as open patches of grassland interspersed between the slightly undulating Lala Palm Veld (Figure 4.9 and Figure 4.10). It is referred to in Grundling (2014) as 'Upland wetlands'. Moll (1980) classifies this area as

Palm Veld, which consists of continuous grass cover of various graminoid species with scattered *Hyphaene natalensis* and *Phoenix reclinata* palms. Slight depressions dominated by grass and sedge species occur in large patches in the Palm Veld. This system occurs on the Kosi-Bay Formation (Grundling et al. 2014). According to local knowledge these moist grassland areas are flooded once every 10 years. Although the whole system is regarded as moist, it would seem as if the slight depressions do play a role in the concentration of water during precipitation events, and will be regarded as 'wetlands' in this study. These wetlands are seasonal and the water table fluctuation plays a more prominent role (Grundling et al. 2014). The size and extent of depressions of these open patches vary to a large degree and the differentiation of the zones in each repetition wetland varies accordingly. Four transects in four wetlands were sampled in this wetland type: two of the transects with three zones and the other two transects with four zones each. The central zone of these transects is usually characterized by a slight depression with grass and sedges. The zones occur in concentric circles around this central zone. All the zones were considered as seasonally or temporarily wet zones. These fertile wetlands, rich in organic matter, are locally utilised for subsistence farming.

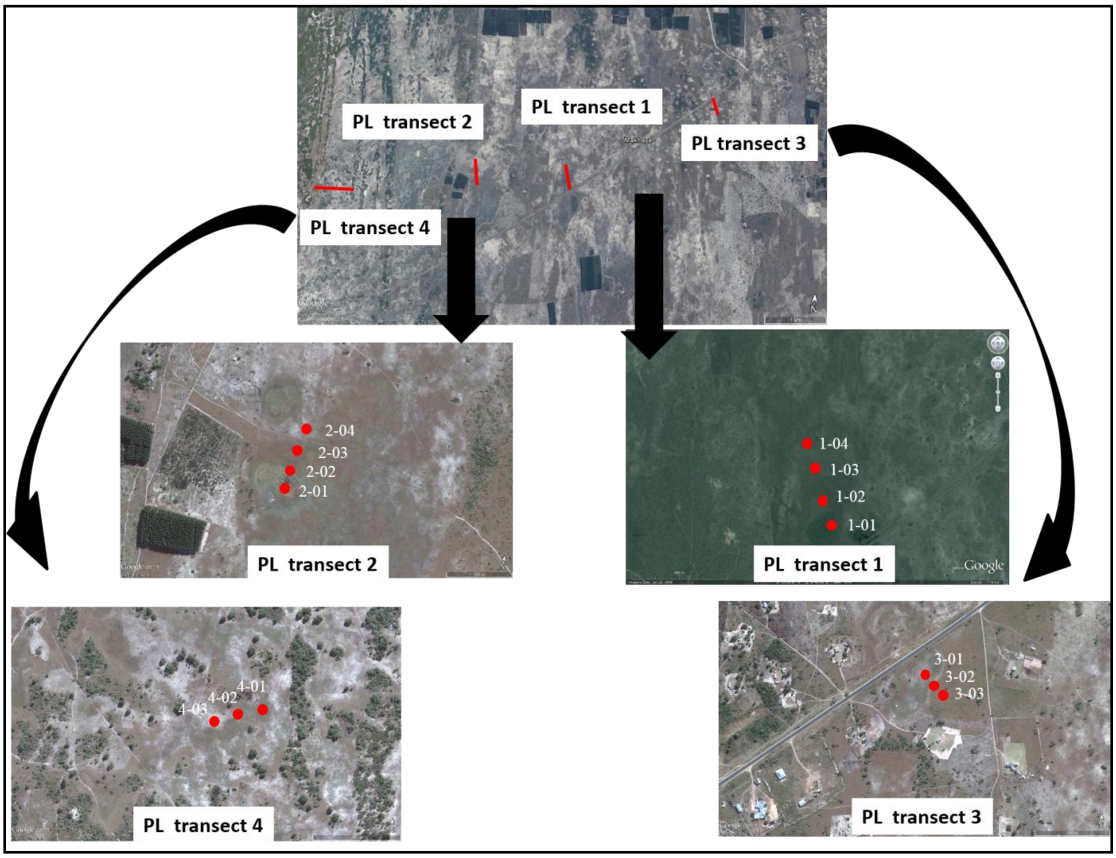

Figure 4.9. Moist Grassland (PL Type) transects.

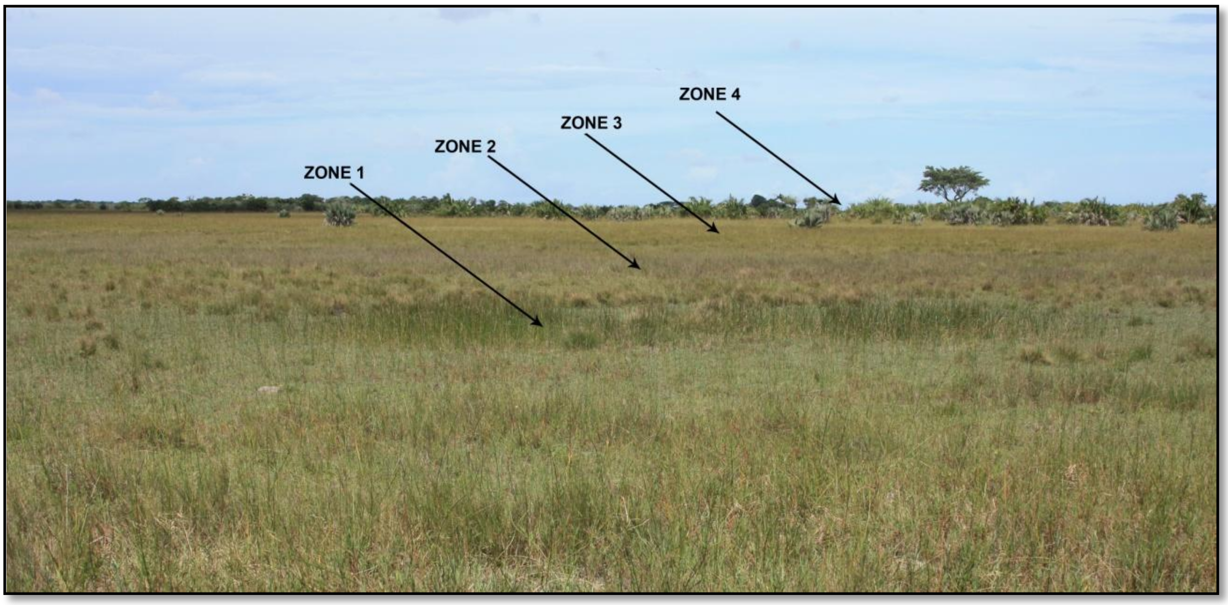

Figure 4.10. An example of the Moist Grassland (PL Type) transects (Pretorius 2011).

4.1.5 Interdunal Depressions (IDD Type)

This wetland type consists of a series of scattered depression-type wetlands occurring between the vegetated coastal dunes a few kilometres west of the shoreline. According to Wright et al. (2000), the dunes surrounding these waterlogged depressions are most probably Holocene barrier and lagoon deposits, and Late Pleistocene sediments which are overlain by fine grained, well sorted Holocene aeolian sand. These dunes form part of the Sibayi Formation. The Interdunal depressions are linked with the regional water table. The soil of the undisturbed wetlands in this system is often high in organic carbon and peaty in character (Grundling 2002). According to Mucina & Rutherford (2006) the IDD System falls in the Maputaland Coastal Belt, a vulnerable vegetation type. Intense local utilization of the fertile peaty soils for sustainable agriculture is very high in these wetlands.

Four zones were identified and sampled per wetland repetition in the IDD Type (Figure 4.11). This wetland type is characterized by a peat substrate in the central portion of the depression, with steep slopes rising sharply around it. The transition from permanently wet to terrestrial is therefore very short. Generally two central zones on peat substrate were identified, one transitional zone on the depression slope, and a fourth zone on the crest of the dune surrounding the depression (Figure 4.12). Most of the wetlands in this system are utilised locally for subsistence agriculture, resulting in very few undisturbed Interdunal depressions left in this system.

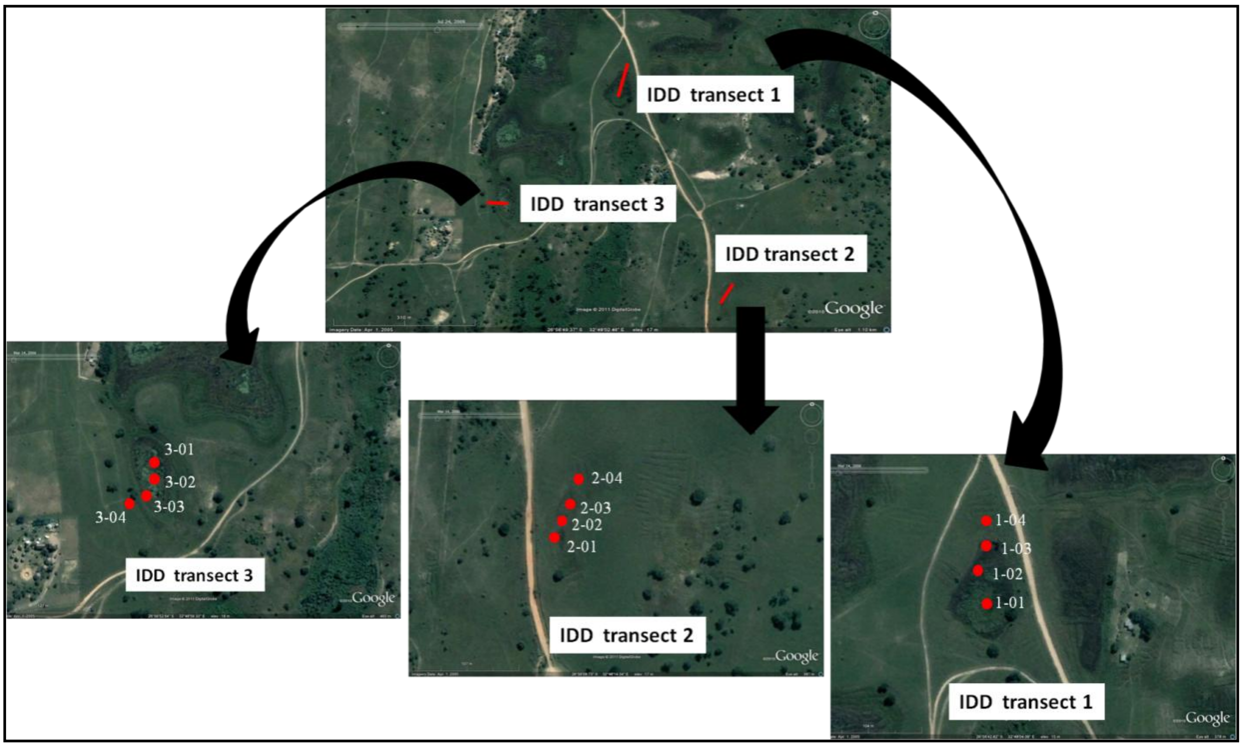

Figure 4.11. The Interdunal Depressions (IDD Type).

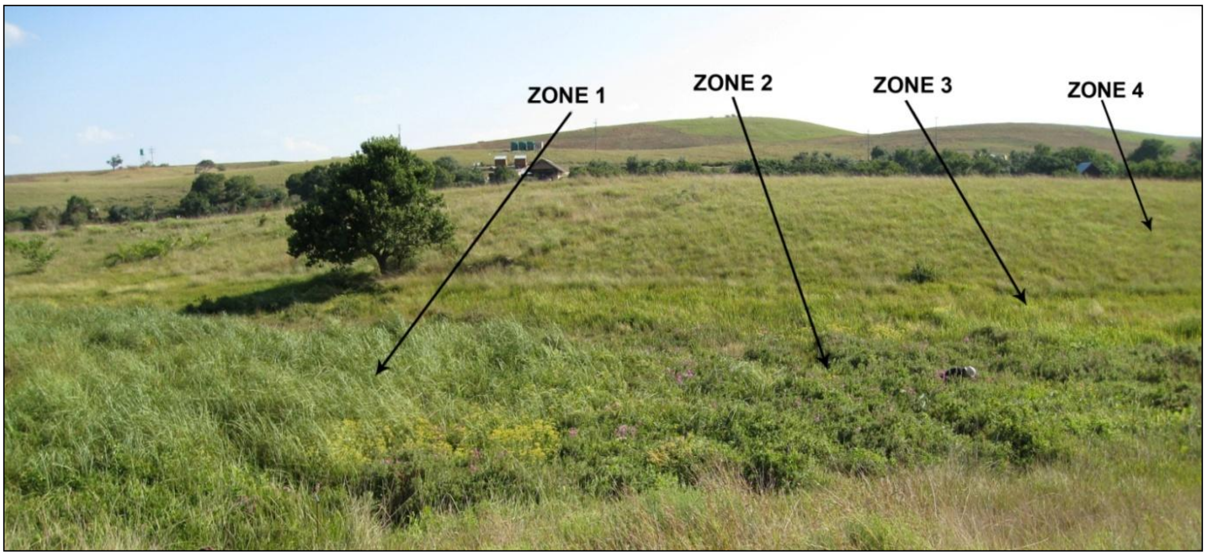

Figure 4.12. An example of the Interdunal Depression (IDD Type) transects (Pretorius 2011).

The sites were selected based on accessibility, safety, land owner consent, data availability, and land use:

Accessibility

Road accessibility to some sites was complicated due to the deep, thick, sandy soils. For this reason the choice of wetland sites was restricted to those occurring next to, or close to the main roads between the Tembe Elephant Park and Lake Nhlange.

Safety

Although a community representative was always present on site during fieldwork, the risk associated with remote areas without cellphone coverage and help close at hand was considered and avoided as far as possible. During field visits in the Tembe Elephant Park an armed guard was always present due to the presence of wild animals.

Land owner consent

Consent was obtained from the Tembe Tribal Authority to work in the area located outside conservation areas. Where wetlands identified were located close to homesteads in the tribal area, consent was also gained from the head of the homestead.

Data availability

Soil and vegetation data, as well as general ecological information, exist for the conservation areas, which is one of the main reasons for the selection of all the wetland repetitions for the Muzi Swamp- and the Tembe Park Perched Pans, even though these systems continue well outside the boundaries of the Park. Some peat studies have also been done on the Muzi Swamp System (Grundling 2002, Thamm et al. 1996). Rainfall data collected from 1951 - 2009 from the South African Weather Service (SAWS), as well as rainfall data and evaporation data for the past 40 years from the ARC-ISCW database are available (SAWS 2009, ARC-ISCW 2009b). A monthly groundwater monitoring programme covering a network of 59 points including wetlands, dams, pans, existed from 2008 to 2012 (Grundling et al. 2014). Because this study forms part of the study controlling this monitoring programme the wetland repetitions were selected as close as possible, if not in the exact spot, to the groundwater monitoring points.

Land use

Most of the wetlands occurring outside conservation areas on the MCP were degraded to some extent. The sandy nature of the soils of the MCP causes soils to be generally infertile, with the result that the local inhabitants of the area utilise the wetland areas extensively for horticultural purposes. Crops such as Amadumbi (*Colocasia esculenta*), sweet potatoes, tomatoes, cabbages, bananas, sugar cane, and spinach are planted in the fertile, moist permanent zone of the wetland systems. Permanently wet peatlands (Interdunal Depressions and Muzi Swamp) are drained by a furrow system, burned, or the peat may be heaped onto raised plots and cultivated (Arndt 2014, Pretorius 2014). As wetlands are usually the closest source of water, wells are often sunk into those wetlands which are not permanently wet. Biomass from wetlands is also utilised as fodder for cattle, as well as for building material (Grundling 2001). It was important for this study to locate pristine wetlands (or as close to pristine as possible) to compare the natural vegetation between the repetitions and treatments, as well as to compare the soil properties. The reasons mentioned above necessitated limited sampling of the Muzi Swamp and Tembe Park Perched Pans (which are located within, as well as outside conservation area boundaries) to the Tembe Elephant Park. The Moist Grasslands and Interdunal Depressions wetland types, however, occur only in the rural area between the Tembe Park and Kosi-Bay.

4.2 Sampling

4.2.1 Soil sampling

Soil sampling took place in June 2010, June 2012, and September 2012 to avoid waterlogged soils as far as possible. In each zone of all the transects soil samples were taken to a depth of 1200 mm. A total of 530 soil samples were collected. Soil profile pits were dug in one transect of each wetland system to enable detailed soil profile description and classification (Soil Classification Working Group 1991) (Addendum A). Thompson bucket-, Edelman-, and Russian peat augers were used to take the samples. Sampling was done in constant depth intervals: 0–50 mm, 50–100 mm, 100–150 mm, 150–200 mm, 200–250 mm, 250–300 mm, 300–400 mm, 400–500 mm, 500–600 mm, 600–900 mm, 900–1200 mm. Sampling was concentrated in the top 300 mm of the profile because of the accumulation of organic matter in this zone. Samples were taken from the profile pit from three sides of the pit to collect a representative sample. The pit was partitioned into intervals using a tape measure and red flagged nails and samples were collected using a bush knife and a geological hammer. In the sites where soil samples were taken using an auger, three holes were augered in close proximity to each other. Soil from the three auger holes was combined into the respective depth increments to acquire a representative sample. Samples were placed into plastic bags marked with a unique code pertaining to the system (treatment), wetland (repetition), zone number, and the specific depth. Soil and environmental data were collected using the Minimum Data Set for Describing Soil Form of the ARC-ISCW (Turner 1995). Photos were taken of the transects, profile pits, auger holes and cores, and the rehabilitation of the sites after sampling. All profile pits and auger holes were filled after sampling.

Soil samples were analysed at the Department of Soil, Crop, and Climate Sciences, University of the Free State. Soil samples were air-dried and large pieces of plant debris were removed. A porcelain mortar and pestle was used to grind subsamples to pass a 2 mm sieve. Soil analyses were conducted using the Handbook of Standard Soil Testing Methods for Advisory Purposes (The Non-Affiliated Soil Analysis Work Committee 1990) except where specified otherwise. The soil nutrients measured in this study are those available for plant uptake. The following soil properties were measured in the laboratory:

pH (H_20)

The pH was measured in water in a ratio of 1:2.5 soil:solution.

Resistance (Ω)

Resistance was measured in a saturated paste.

Soil Organic Carbon (SOC) (% and $mg.kg^{-1}$)

The amount of soil organic carbon was determined using the Walkley-Black method. This method was chosen as a result of the report by Grundling *et al*. (2010). Generally 1 gram of soil was used for this analysis, but in the cases of the peat samples as little as 0.1 g soil was used. This analysis was done in duplicate (and some high SOC samples in triplicate) due to the low amounts of soil that had to be used.

Nitrogen (mg.kg^{-1})

Nitrogen content was determined using the Kjeldahl method. Most of the soil samples were analysed using 2 g of soil, but this varied between 0.2 g for the samples with high concentration of nitrogen and 4 g for the samples with low concentrations of nitrogen.

C/N Ratio

The ratio of organic carbon to nitrogen was calculated by applying the equation: C/N = Organic Carbon (mg.kg^{-1}) / Nitrogen (mg.kg^{-1}).

Iron and Manganese (mg.kg^{-1})

"Free" Fe and Mn were determined by the Citrate Bicarbonate-Dithionate (CBD) method. This method extracts the "non-crystalline" iron and manganese *i.e.* Fe and Mn not bound in the lattice of clay minerals.

Exchangeable Cations and Cation Exchange Capacity (cmol$_c$/kg)

Cations and the Cation Exchange Capacity (CEC) was determined using 1 N NH_4OAc (ammonium acetate) adjusted to a pH 7 solution. Ca, Mg, Na, and K were determined by Atomic Absorption Spectroscopy.

Particle Size Analysis (PSA) (texture) (%)

The percentage coarse- (> 0.5 mm), medium- (0.5 – 0.25 mm), and fine (0.25 – 0.05 mm) sand, coarse (0.05 – 0.02 mm) and fine (0.02 – 0.002) silt, and clay (< 0.002 mm) were determined for selected samples using the pipette method described by Day (1965). Data could not be obtained for the samples very high in organic matter due to the difficulty in removing organic matter from high organic substrates during the PSA procedure.

Soil Colour

The matrix colour of each sample was described using a Munsell soil chart.

4.2.2 Vegetation surveys

Vegetation surveys were conducted during the growing season in March 2010. Vegetation surveys were conducted along the transects in all the wetlands in the various wetland types. Relevés were compiled in each plot. The Braun-Blanquet cover abundance scale was used to allocate a value to each occurring plant species (Westhoff & Van der Maarel 1987):

- r - very rare (usually a single individual) and with negligible cover;
- + - present but not abundant and with a small cover (less than 1% of the plot area);

- 1 - numerous but covering less than 1% of the plot area, or not so abundant but covering 1-5% of the plot area;
- 2 - very numerous and covering less than 5% of the plot area, or covering 5-25% of the plot area;
- 3 - covering 25-50% of the plot area;
- 4 - covering 51-75% of the plot area;
- - covering 76-100% of the plot area.

Plots were 2 m x 2 m, based on the size and variety of the plant communities present in the wetlands. Sampling plots larger than 4 m2 may cross the zone boundary and result in the inclusion of other vegetation communities in the relevé. Vegetation and Environmental data were collected onto the South African Wetland Vegetation Survey Field Data Form (Sieben 2011) for each plot. Plant species were identified in field, while the unknown plant species were collected, oven-dried, and identified at the South African National Biodiversity Institute and the HGWJ Schweikerdt herbarium at the University of Pretoria.

4.3 Statistical analysis

4.3.1 Soil data analysis

Chapter 6

A Principal Component Analysis was conducted using the PC-ORD software (McCune & Mefford 1999) to investigate the relationship between wetland types and -zones, and determine the main influencing environmental variables on these relationships. Since clay content was not available for all the wetland sites, a constant of 1 was added to compensate for the absent data. Thereafter all the data was log- transformed to improve the linearity of the environmental relationships (Mccune & Grace 2002). The pH data was not transformed, as it is a log-value already.

The variation of soil properties in the wetland zones down a topographical gradient was investigated by fitting a series of mixed models in order to investigate various aspects of the data. The various mixed models were fitted using the SAS software package (version 9.22, SAS procedure MIXED; SAS 2009). Generally the data were modelled as a function of the factors 'Type', 'Zone', 'Transect' and 'Depth'. Only data to a depth of 400 mm were analysed, as it was statistically determined using one-way ANOVA (significance at $p < 0.05$) that most variation in soil properties occurs in the top 400 mm of a soil profile (refer also to Chapter 5). The following depth increments were used: 0-50, 50-100, 100-150, 150-200, 200-250, 250-300, and 300-400 mm. The 11 variable measurements (C, N, Ca, K, Mg, Na, Fe, Mn, CEC, pH and resistance) constitute the dependent variables in the statistical analyses. The 11 dependent variables were analysed separately. The objectives were to:

- Assess the effects of the factors 'Type' and 'Depth', and
- Investigate differences with respect to 'Zone'.

The series of mixed models (models 1 to 5) are described below:

Models 1 and 2

In models 1 and 2, data from all five wetland types were analysed jointly by fitting a linear mixed model with the following categorical (class) effects:

- **Fixed effects:** type, zone, type*zone, depth, type*depth, zone*depth, type*zone*depth
- **Random effects:** transect*type, transect*type*zone

If the 'transect*type' random effect were to be left out, the resulting mixed model would be equivalent to a split-plot ANOVA; where transect*type*zone identifies the sampling points, with between-plot factors type and zone, and within-plot factor depth. The additional random effect transect*type was fitted in order to model correlation along transects.

Model 1 was fitted to the data as measured (untransformed), while Model 2 was fitted to the log-transformed data (natural logarithm). When analysing the untransformed data, plots of the residuals against predicted values generally suggested that the variance increased with the mean (funnel shaped residual plots). When analyzing the log-transformed data, the residual variance seemed to stabilize. Therefore, all subsequent analyses were carried out using the log-transformed data, with the exception of the variable pH which was analysed using the untransformed data (since pH is already a log-value).

Generally the type*zone and type*zone*depth interaction terms were statistically significant. The effect of between-zone differences therefore depended on the type of wetland. As a result further analyses were carried out separately for the different wetland types.

Model 3

The following mixed model was fitted to data from the five wetland types separately:

- **Fixed effects**: zone, depth, zone*depth
- **Random effects:** transect, transect*zone

Based on this model, (least squares) means for the various zones in each wetland type were calculated. In order to assess the differences between zones, pairwise differences between the zone means and associated P-values were calculated.

The data were analysed on the log-scale, so that the antilog of the zone means were geometric mean values of the measurements. Similarly, the antilog of the pairwise differences between zone means was the ratios of the geometric means.

Because Model 3 did not assume that the effect of depth was linear (depth was fitted as a categorical effect in Model 3) and because Model 3 did not assume that the zone*depth interaction was not significant, the results from this model were valid for all dependent variables and wetland types.

Model 4

Where the zone*depth interaction term in Model 3 was not significant, this interaction term was dropped from the model, and the following mixed model was fitted to data from the five wetland types separately:

- **Fixed effects:** zone, depth_c, depth
- **Random effects:** transect, transect*zone

The variable depth_c represents depth fitted as covariate. The variable depth_c is included in Model 4 in order to test whether depth as categorical variable, fitted after depth_c, remains significant. If depth fitted after depth_c is found not to be significant, the effect of depth is linear, and can be modelled using the covariate depth_c. Generally, but not always, the factor depth was not significant.

Model 5

In the cases where the factor depth was not significant in Model 4, this factor was dropped, and the covariate depth_c was continued to be fitted with the following mixed model (from the five wetland types separately):

- **Fixed effects:** zone, depth_c
- **Random effects:** transect, transect*zone

As for Model 3, (least squares) means for the zones were calculated and pairwise differences between the zone means and associated P-values were calculated.

As with model 3, the data were analysed on the log-scale. Therefore the antilog of the zone means were geometric mean values of the measurements. Similarly, the antilog of the pairwise differences between zone means was the ratios of the geometric means.

Chapter 8

The Munsell system has three components: Hue (a specific colour), Value (lightness and darkness), and Chroma (colour intensity), which are arranged in books of colour chips. Soil is then matched visually and assigned the corresponding Munsell notation.

Indices to determine the correlation between organic carbon and soil colour

The following relationships were determined to establish which give the best correlation between soil colour and SOC:

- **Hue Value and Chroma: wet and dry**.
- **Dry Value - Wet Value.** The ΔValue from dry to wet was correlated against SOC. Soil generally becomes bleached when it is dried, while SOC retains its dark colours whether it is dry or wet, therefore the colour change in the sandy soil samples will be higher than in the

high organic soil samples. Only the Value component of the Munsell system was used, as this showed the best correlation with SOC.

- **Dry Value + Wet Value**. Similar to above.
- **Mokma & Cremeens (1991)** developed a horizon colour index based on matrix colour, size and colour of mottles and continuity and colour of clay films. The colour of mottles was not determined in this study, as the soil was ground and sieved and the resulting matrix colour read. No clay cutans were observed in the soil in this study. Therefore the colour index of the soil matrix was adapted, and determined by*: numeric Hue + (8 - Chroma).*
- **Evans & Franzmeier (1988)** developed an index to combine Hue and Chroma. To account for the high Hue values of wet soils a Hue index "hi" was calculated by subtracting the hue number from 30 and assigning neutral hues a hi value of 2.5. Thus hi numbers are 2.5YR = 17.5, 5YR = 15, 7.5YR = 12.5, 10YR = 10, 2.5Y = 7.5, 5Y = 5.0. These conventions are arbitrary, and the number 30 was chosen to keep the 'hi' value positive. The equation 'hi + Chroma' was used to combine the effects of Hue and Chroma.
- **Godlove (1951) and Melville & Atkinson (1985)** propose that Euclidean distance is a valid measure of perceived colour differences, and to obtain a single numerical value for this distance with the equation $\Delta E = (2C_1C_2\ [1 - \cos (3.6 \times \Delta H)] + (\Delta C)\ 2 + (4\Delta V)\ 2)^{½}$ where C_1 and C_2 are the Chroma units of two colours separated by ΔC Chroma units, ΔH Hue units and ΔV Value units.
- **Van Huyssteen (1997)** developed a number of indices to correlate the degree of wetness with soil colour.
- **Effect of substrate.** From the literature review it is apparent that texture class, land use, size of geographic area, and climatic region has an influence whether there is a relationship between SOC and soil colour, and how significant this relationship is. Since all the wetland systems occur within in one climatic region, the land use was similar, and none of it was under cultivation, therefore only the effect of texture in soil colour was determined. Chapter 5 and 7 indicated that there are three main substrate types that are highly influential in wetlands on the MCP. The data were analysed per substrate type:
    - High Organic soils, where SOC > 10% (Soil Classification Working Group, 1991);
    - Clay soil, where the clay fraction is > 10% (as per Pretorius, 2011); and
    - Sandy soil, where the clay fraction is < 10% (as per Pretorius, 2011).

There were no data for the Utilised Perched Pans (DP Type) for any of the soil colour analysis, therefore this wetland type was omitted in this chapter.

<u>Segmented quantile regression models</u>

It is not unusual that relationships between soil properties cannot be described by conventional correlation or regression analysis. Blavet et al. (2000) suggests that colour limits could be defined when constructing relationships between soil morphology and the duration of water saturation. This is because there tends to be a scatter of values of which the only meaningful feature may be a boundary line that separates a zone of reality from that of imagination (Mills et al. 2006).

It is believed that envelopes delineated by segmented quantile regression would provide greater insight into relationships between two soil parameters than would straight-line regression (Koenker and Hallock 2001). Quantile regression models are useful when the response variables are affected by more than one factor, when the response is different to different factors, when not all applicable factors are measured and when there is an interaction of multiple factors (Cade and Noon 2003). Unlike multiple regression and multivariate analyses, the quantile regression approach illustrates that the expression of the dependent variable can only occur within a limited range of a particular variable, but that this potentially maximal expression is not guaranteed. Conversely, there may be a predictably minimal expression of the dependent variable over one or more ranges of the environmental variable (Mills et al. 2006). Segmented quantile regression would result in an understanding of the relationships between SOC and soil colour by demarcating zones of potentially maximal and predictably reduced expression (Mills et al. 2006).

The idea behind quantile regression is to fit a regression line through a part of a set of data points to create a response envelope (Mosteller and Tukey 1977). Inside of this envelope will be the zone of reality, where actual data points occur; while outside of this envelope would be the imagination zone, where data points could, but do not occur. Depending on the quantiles chosen to create this regression line a certain percentage of data points will occur beneath it (Figure 4.13; Van Zijl et al. 2014, Medinsky 2006, Mills et al. 2006).

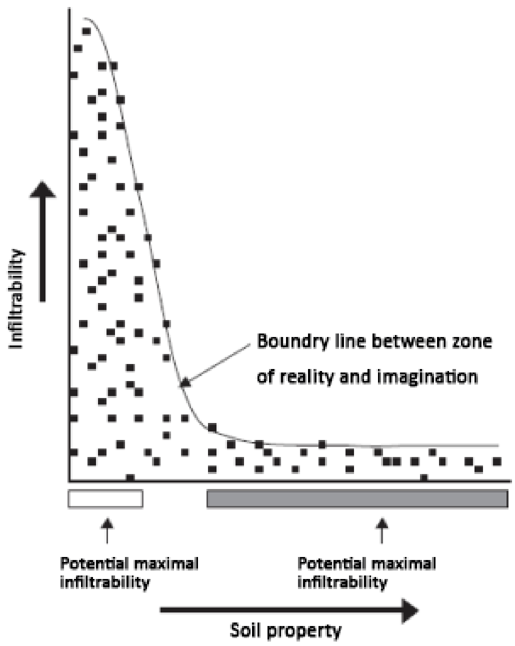

Figure 4.13. Hypothetical relationship between infiltrability and a soil property showing a boundary line that divides a zone of reality from that of imagination (Mills et al. 2006).

There should be a balance between a sufficient number of classes and a sufficient number of data points in each class to accurately reflect the distribution of the response variable over the particular range of the independent variable. This is a somewhat subjective choice. The boundary lines presenting 0.9 and 0.1 quantiles were calculated in MS Excel, as this adequately reduced the amount of outliers. To construct the boundary lines the data were sorted in ascending order according to the independent variable and subdivided into a number of classes with equal number of samples in each class. The number of data points per class were mostly 50, although some were as low as 20 and as high as 99 in some classes. Mean soil variables and quantiles (0.1 and 0.9) were obtained for each class. Regression lines fitting the 0.9 quantile were selected.

Topsoil colour as indicator of wetland boundaries

The four different wetland systems were analyzed separately. For each wetland system the zones were statistically compared to determine whether there are different colour values moving from the outside of the wetland to the inside of the wetland. Significant differences between topsoil colours for the various zones could then be used as an indicator of wetland boundaries. This analysis was done for a selected number of Munsell colour indices.

A one-way between-groups ANOVA was conducted to determine whether the colour indices can be used to differentiate between the various zones in the various wetland types. Normality was assumed by examining the Shapiro-Wilk test result ($p > 0.05$). The assumption for homogeneity of variances was investigated using Levene's statistic ($p > 0.05$). In cases where the assumption for homogeneity of variance were violated ($p < 0.05$), a Welch ANOVA was applied. A Tukey Post-Hoc test was applied to the ANOVA results, and a Dunnett Post-Hoc test to the Welch ANOVA test results.

4.3.2 Vegetation classification, analysis, and ordination

The vegetation relevés were captured into a database for floristic data called Turboveg for Windows 1.97 (Hennekens 1996) after which the database was exported as a Cornell Condensed species file into JUICE 6.5 (Tichý 2002). JUICE is a computer programme for editing, classifying and analysing floristic data into phytosociological tables. No species were removed prior to analysis. A TWINSPAN classification as well as a subsequent modified TWINSPAN (Rolecěk et al. 2009) was performed in JUICE. The final classification was used to compile a phytosociological table in JUICE, which was manually refined (Brown et al. 2013) to clearly indicate the different plant communities, sub-communities, floristic variation as well as the relationship between these communities. A dendrogram to illustrate hierarchical levels of the classification of communities, was obtained for the classifications of the sites.

A small number of relevés had to be omitted from the original dataset as environmental data were not available for all the sites during the ordination. All analyses were done in the multivariate software PC-ORD 6.19 (Mccune & Mefford 2011).

4.3.3 Indicator Species Analysis

McCune & Grace (2002) present an Indicator species analysis (ISA) in the multivariate software PC-ORD which determines and describes the value of individual species to a particular group and its associated environmental conditions, by combining information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group.

Indicator values for each species are tested for statistical significance by a Monte Carlo permutation test with 999 runs.

PC-ORD 6.19 was used to conduct this analysis. All species with Indicator Values (IV) of 20% and higher and with Monte Carlo significance levels of higher than 95% ($p < 0.05$) have been listed as characteristic of groups. In cases where the cut-off level of 20% was not obtained, values between 10 and 20% were also reported, as long as the significance levels of $p < 0.05$ were met (Dufrêne & Legendre 1997). In some cases, there were no indicator species for a group. According to Sieben (2014), these communities can be regarded as "rump" communities, which are mostly characterized by the absence of certain indicator species.

The wetland types were assessed individually in order to obtain the species indicative of each separate type and its respective zones, regardless of whether this species may occur or be dominant in one of the other wetland types as well.

4.3.4 Weighted Averaging

For each relevé a community index was calculated using the approach of Scott et al. (1989). The following formula calculates the mean of the species' index value, by weighting each species' index by the relative importance of that species in the plot:

$$WA = \sum_{i=1}^{n} (W_i S_i) / \sum_{i=1}^{n} W_i$$

Where *WA* is the weighted average, W_i is the weight or importance of species *i* in the relevé, S_i is the index value of species *i*, and *n* is the number of species in the relevé. In this study, the weight (W_i) of the species was determined using the species cover abundance values. These Braun-Blanquet values were transformed as follows (Table 4.2):

Table 4.2. The weight (W_i) value assigned to each species according to their Braun-Blanquet cover values.

Braun-Blanquet cover values	Description of the cover values	Assigned corresponding weight (Wi)
5	76 - 100% of the plot area	5
4	51 - 75% of the plot area	4
3	25 - 50% of the plot area	3
2	5 - 25% of the plot area	2
1	1-5% of the plot area	1
+	less than 1% of the plot area	0.5
r	usually a single individual with negligible cover	Removed

All species with an 'r' Braun-Blanquet cover abundance value were removed prior to analysis due to the negligibility of the weight of the species.

The index value (S_i) was determined using the 'Annotated checklist of the wetland flora of southern Africa' (Glen unpublished). This checklist assigns a wetland indicator status based on the probability of occurrence in a wetland. Table 4.3 is an adaptation of Table 3.3, indicating the index value which was assigned to each wetland indicator status and used in the analysis.

Table 4.3. The criteria on which the wetland indicator status is based (adapted from Glen (undated)).

Wetland Indicator Status	% Probability of occurring in a wetland	Index Value
Obligate wetland plant	> 99%	1
Facultative wetland plant+	65–98%	2
Facultative wetland plant	50–64%	3
Facultative wetland plant–	25–49%	4
Upland plant	1–24%	5

The use of the term 'Opportunistic plant' in category 5 was replaced with 'upland plant'. Glen (Unpublished) did not list all the plants which do not occur in wetlands, and therefore category 5 contains those general or pioneer species which do not have a place in any of the other categories. For the purpose of this study, however, the category had to be changed to be similar to that of Reed (1988) in order to be able to apply the weighted averaging scale indicated in Table 4.3.

According to Scott et al. (1989), it is accepted for the data collector to assign a species to a different category based on literature, and/or personal experience. Based on experience of the study area as well as consultation with the author of the Annotated checklist of the wetland flora of southern Africa (R. Glen pers. comm. 2015) the following species were moved between categories (Table 4.4):

Table 4.4. The species that were assigned to a different Wetland Indicator category.

Species	Wetland Indicator Status as per Glen (Undated)	New Indicator Status
Centella asiatica	Facultative	Facultative +
Cyperus natalensis	Obligate wetland plant	Facultative
Dactyloctenium aegyptium	Opportunist plant	Facultative
Hibiscus cannabinus	Opportunist plant	Facultative
Hibiscus trionum	Opportunist plant	Facultative
Marsilea species	Unlisted	Obligate wetland plant

Unknown species were removed from analysis. Species which could only be identified up to genus level was also removed. For a full species list with assigned values, refer to Addendum D.

The Weighted Averaging function in the multivariate software PC-ORD (McCune & Mefford 2011) was used to obtain a graphical representation of the WA scores of all the relevés along an axis. The software SPSS version 22 (IBM Corporation 2013) was used for other statistical analysis and graphical representations. Index values results are interpreted in the following manner, according to the method of (Tiner 1999) (Table 4.5):

Table 4.5. Criteria on the interpretation of the WA scores (Tiner 1999).

WA score	Criteria
< 2	Site is a wetland
2 – 2.5	Site has a good probability of being a wetland, but soil and hydrology should confirm
2.5 – 3.5	Inconclusive regarding its prevalence to wetlands or uplands (other criteria must be taken into account)
3.5 – 4	Site has a good probability of being an upland site, but soil and hydrology should confirm
> 4	Upland site

Chapter 5
SOIL TYPES OF WETLANDS ON THE MCP

5.1 Introduction

There is a lack of studies investigating wetland soils on the Maputaland Coastal Plain (MCP) (Sieben 2014). In order to understand the differences between the five wetland types and their respective zones, the properties of these wetlands along a topographic gradient were investigated. The aim of this chapter is to describe the morphological, chemical, and physical properties which characterise the five different wetland types on the topographical gradient. The full profile descriptions are given in Addendum A.

5.2 Soil form distribution across wetland types and zones

Fifty-nine profiles were classified, of which 19 were done by investigating profile pits, and 40 by hand auger. The soil profile pits were dug in one transect in each of the wetland systems. All profiles were identified up to a depth of 1200 mm. One sample site, PP 1-01, could not be classified, as it was inundated by water to such an extent that samples could not be retrieved. Table 5.1 provides a list of the profiles. Table 5.2 indicates the distribution and prevalence of 14 identified soil forms. The most common soil type (Soil Classification Working Group, 1991) is the Fernwood soil form, which occurs in 25% of the sites; followed closely by the Champagne soil form in 20% of the sites. Six soil forms occurred only once.

Table 5.1. List of the 59 profiles.

Profile	Coordinates	Altitude	Soil Form	Method	Profile	Coordinates	Altitude	Soil Form	Method
MS 1-01	27°00'30.73"S 32°30'11.18"E	47	Champagne	Profile Pit	DP 3-01	27°04'06.05"S 32°28'21.04"E	49	Katspruit	Augered
MS 1-02	27°00'31.97"S 32°30'12.84"E	50	Champagne	Profile Pit	DP 3-02	27°04'06.09"S 32°28'21.01"E	49	Katspruit	Augered
MS 1-03	27°00'32.47"S 32°30'14.02"E	48	Westleigh	Profile Pit	DP 3-03	27°04'07.04"S 32°28'20.05"E	49	Molopo	Augered
MS 1-04	27°00'33.01"S 32°30'14.77"E	48	Longlands	Profile Pit	PL 4-01	27°03'19.84"S 32°36'49.32"E	78	Champagne	Augered
MS 4-01	27°00'48.48"S 32°30'03.21"E	40	Champagne	Augered	PL 4-02	27°03'19.20"S 32°36'49.56"E	78	Fernwood	Augered
MS 4-02	27°00'48.80"S 32°30'04.97"E	40	Champagne	Augered	PL 4-03	27°03'18.65"S 32°36'49.94"E	78	Fernwood	Augered
MS 4-04	27°00'49.26"S 32°30'07.66"E	41	Westleigh	Augered	PL 4-04	27°03'17.48"S 32°36'50.31"E	78	Fernwood	Augered
MS 4-05	27°00'49.30"S 32°30'08.51"E	42	Brandvlei	Augered	PL 3-01	27°03'13.01"S 32°37'49.06"E	77	Fernwood	Augered
MS 6-01	26°59'49.24"S 32°30'20.34"E	39	Champagne	Augered	PL 3-02	27°03'11.40"S 32°37'48.57"E	77	Longlands	Augered
MS 6-02	26°59'50.70"S 32°30'21.95"E	39	Champagne	Augered	PL 3-03	27°03'09.78"S 32°37'47.79"E	77	Fernwood	Augered
MS 6-03	26°59'50.29"S 32°30'23.68"E	41	Fernwood	Augered	PL 3-04	27°03'05.87"S 32°37'45.85"E	77	Fernwood	Augered
MS 6-04	26°59'51.30"S 32°30'26.39"E	41	Brandvlei	Augered	PL 5-01	27°02'23.15"S 32°39'17.63"E	77	Fernwood	Augered
PP 1-01	27°01'23.16"S 32°29'30.88"E	49	*Inundated*	Augered	PL 5-02	27°02'22.25"S 32°39'19.19"E	77	Fernwood	Augered
PP 1-02	27°01'23.08"S 32°29'30.82"E	49	Katspruit	Augered	PL 5-03	27°02'24.01"S 32°39'22.13"E	77	Fernwood	Augered
PP 1-03	27°01'23.11"S 32°29'30.69"E	49	Sterkspruit	Augered	PL 6-01	27°03'31.67"S 32°35'23.18"E	75	Fernwood	Profile Pit
PP 3-01	27°01'34.58"S 32°29'25.02"E	42	Katspruit	Profile Pit	PL 6-02	27°03'32.69"S 32°35'22.73"E	75	Fernwood	Profile Pit
PP 3-02	27°01'34.58"S 32°29'25.05"E	42	Katspruit	Profile Pit	PL 6-03	27°03'34.05"S 32°35'23.28"E	75	Fernwood	Profile Pit
PP 3-03	27°01'34.56"S 32°29'25.02"E	42	Valsrivier	Profile Pit	IDD 3-01	26°56'59.47"S 32°49'12.51"E	17	Champagne	Profile Pit
PP 2-01	27°01'26.61"S 32°29'28.00"E	49	Sterkspruit	Augered	IDD 3-02	26°56'59.35"S 32°49'12.63"E	17	Fernwood	Profile Pit
PP 2-02	27°01'26.57"S 32°29'28.10"E	49	Sterkspruit	Augered	IDD 3-03	26°56'59.44"S 32°49'13.29"E	17	Fernwood	Profile Pit
PP 2-03	27°01'26.50"S 32°29'28.18"E	49	Sterkspruit	Augered	IDD 3-04	26°56'59.43"S 32°49'14.68"E	18	Namib	Profile Pit
DP 2-01	27°03'53.06"S 32°28'26.04"E	48	Katspruit	Profile Pit	IDD 2-01	26°56'41.95"S 32°49'03.28"E	16	Champagne	Augered
DP 2-02	27°03'53.06"S 32°28'25.06"E	48	Katspruit	Profile Pit	IDD 2-02	26°56'41.51"S 32°49'03.14"E	16	Champagne	Augered
DP 2-03	27°03'53.06"S 32°28'25.03"E	48	Kroonstad	Profile Pit	IDD 2-03	26°56'40.71"S 32°49'02.62"E	17	Namib	Augered
DP 2-04	27°03'53.07"S 32°28'24.08"E	48	Montagu	Profile Pit	IDD 2-04	26°56'40.19"S 32°49'02.15"E	18	Namib	Augered
DP 2-05	27°03'53.09"S 32°28'24.00"E	48	Sepane	Profile Pit	IDD 5-01	26°56'53.11"S 32°48'54.81"E	20	Champagne	Augered
DP 1-01	27°03'56.09"S 32°28'23.09"E	50	Westleigh	Augered	IDD 5-02	26°56'53.47"S 32°48'54.70"E	21	Champagne	Augered
DP 1-02	27°03'56.06"S 32°28'24.01"E	50	Longlands	Augered	IDD 5-03	26°56'53.65"S 32°48'54.44"E	21	Namib	Augered
DP 1-03	27°03'56.02" S32°28'24.01"E	50	Kinkelbos	Augered	IDD 5-04	26°56'53.91"S 32°48'54.19"E	22	Namib	Augered
DP 1-04	27°03'55.08"S 32°28'24.02"E	50	Longlands	Augered					

Table 5.2. The distribution of soil forms (Soil Classification Working Group, 1991) in wetland sites.

Soil Form	Horizon sequence	Prevalence
Fernwood	Orthic A E Unspecified	26% (15 profiles)
Champagne	Organic O	21% (12 profiles)
Katspruit	Orthic A G	12% (7 profiles)
Namib	Orthic A Regic Sand	10% (6 profiles)
Longlands	Orthic A E Soft Plinthic B	7% (4 profiles)
Sterkspruit	Orthic A Prismacutanic B	7% (4 profiles)
Westleigh	Orthic A Soft Plinthic B	5% (3 profiles)
Brandvlei	Orthic A Soft carbonate	3% (2 profile)
Kinkelbos	Orthic A E Neocarbonate B	2% (1 profile)
Kroonstad	Orthic A E G	2% (1 profile)
Valsrivier	Orthic A Pedocutanic B Unconsolidated material without signs of wetness	2% (1 profile)
Sepane	Orthic A Pedocutanic B Unconsolidated material with signs of wetness	2% (1 profile)
Montagu	Orthic A Neocarbonate B Unspecified material with signs of wetness	2% (1 profile)
Molopo	Orthic A Yellow-Brown Apedal B Soft carbonate	2% (1 profile)

The distribution of soil forms is somewhat associated with wetland type (Figure 5.1) and zone (Figure 5.2). The Fernwood and Champagne soil forms are restricted to the sandy and organic wetland types (Muzi Swamp-, Moist Grasslands-, and the Interdunal Depressions types), in varying frequencies. The only other soil form present in the sandy Moist Grasslands is the Longlands form. The Interdunal Depressions are further characterised by the sandy Namib soil form. The Tembe Park Perched Pans are characterised by the clay-dominated Katspruit-, Sterkspruit-, and Valsrivier soil forms; while the

Utilised Perched Pans have a much greater variety of soil forms present, many of which occurs only once.

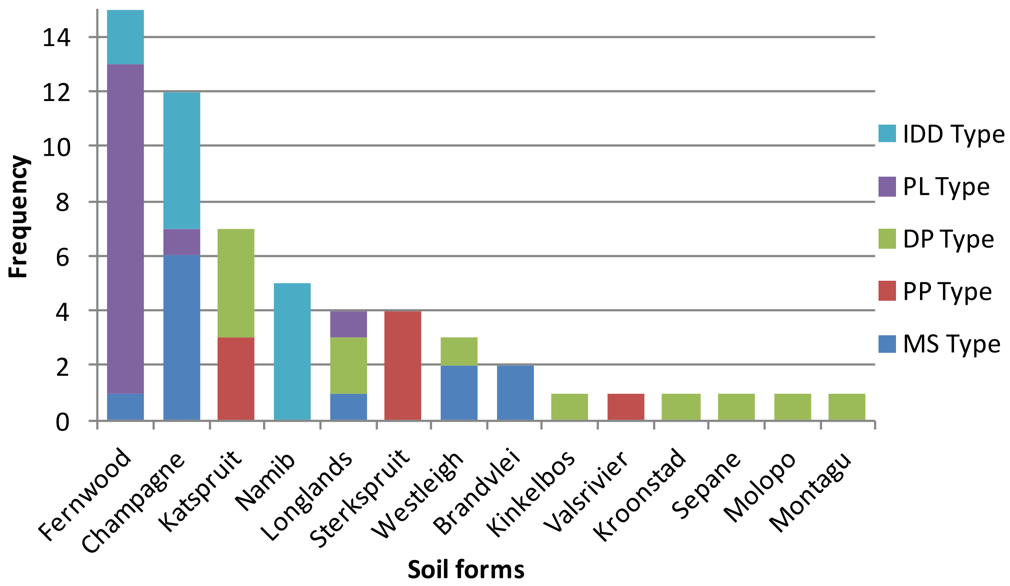

Figure 5.1. Soil form distribution across wetland types.

There are clear trends with the distribution of soil forms across the topographic gradient (Figure 5.2). The Champagne soil form only occurs at the bottom of the catena (zones 1 and 2). The Fernwood, Katspruit, Sterkspruit and Westleigh soil forms can occur anywhere on the slope, although each are limited to only certain wetland types. The rest of the soil forms are limited to the upper slopes of the catena.

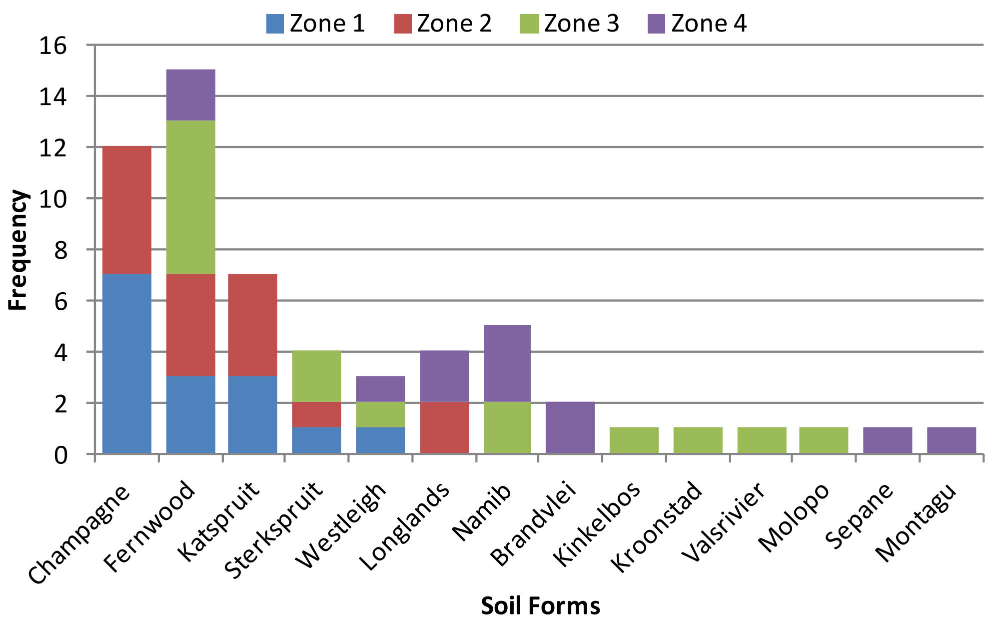

Figure 5.2. Soil form distribution across wetland zones.

5.3 Profile description

The in-depth characterisation of the various soil profiles will be discussed per wetland type. For each wetland type an example of a transect is illustrated, as well as the average values of the three transects in each wetland type, per analysed soil property. The standard error is not depicted on these graphs, as the aim of this chapter is not the similarity of the zones, but rather to indicate the average fluctuation in the various types and zones. The comparison between zones is discussed in Chapter 6. Due to high variation between the transects in some of the wetland types, the Muzi Swamp- and Utilised Perched Pans were discussed at hand of only one of the transects.

5.3.1 The Muzi Swamp (MS Type)

Morphological and physical properties

The Muzi Swamp (MS Type) is characterised by high organic soils in the centre section of the peatland, with duplex soil with calcimorphic clays on the edge of the linear system (Grundling et al. 2014, Matthews et al. 2001, Watkeys et al. 1993). Calcium carbonate is present in varying quantities throughout the whole wetland (Grundling et al. 2014). There is at least one profile in each of the three transects, which consist of a soft carbonate horizon (Figure 5.3). Within the peatland itself, the high organic soil is often alternated by layers of calcium carbonate (Figure 5.4), where it appears as if the water is moving on top of the chalk layer. Horizons that are indicative of water movement, such as plinthic horizons and materials with signs of wetness, are very common in all positions on the slope. Both hard plinthic B as well as soft plinthic B horizons occur. A variety of colours and sizes of mottles occur in almost all horizons, most of which are of oxidised iron oxide and illuvial iron and humus origin. Mottles are often absent in the Orthic A horizon at the top of the slope, in peat layers, and in E-horizons.

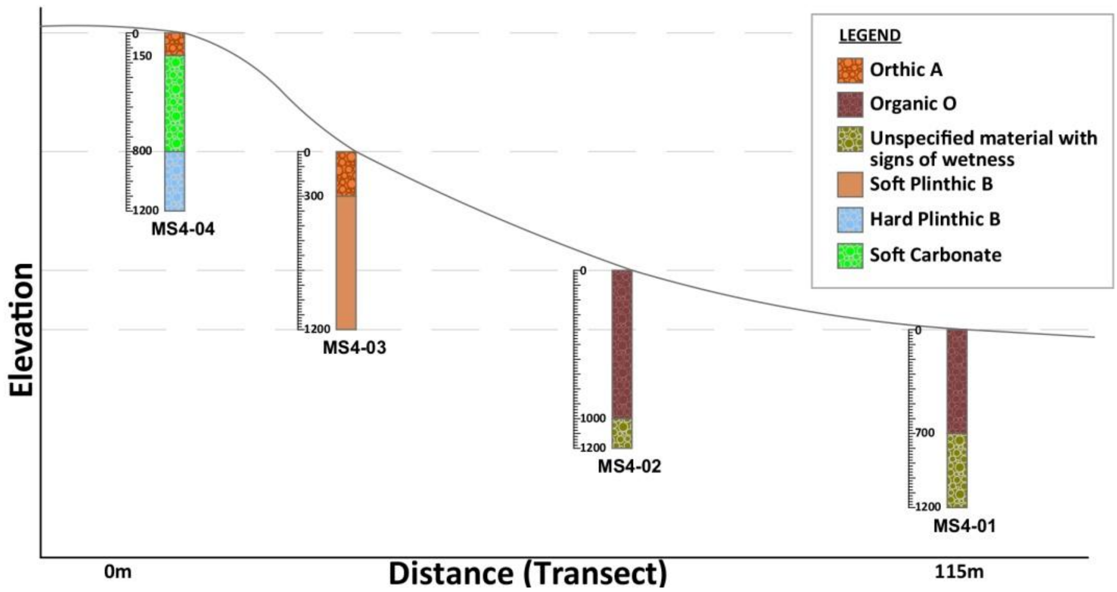

Figure 5.3. An example of a catena in the MS Type.

Figure 5.4. Example of alternating calcium carbonate and peat layers.

The wetland system is driven by groundwater discharge where the high organic soils are present and water moves laterally over the duplex soil from the upland sides (Matthews 2007). The water table was found at varying depths during sampling. Generally it was much deeper than what is expected in a peatland. In one transect the water table was found at 400 – 500 mm depth where peat horizons were present, and was not reached at all in the two profiles on the slope. In the transect featured in Figure 5.3 the water table was encountered in the unspecified material with signs of wetness horizon - underneath the peat horizons. In the third transect the water table was not reached at all. The high organic soils in this transect also did not meet the criteria to classify as peat.

The MS Type has soils in a relatively wide spread of textural classes (Figure 5.5). Samples are notably absent from the sand and loamy sand classes; as well as the silt classes. Only a few samples are classified as pure clay. The Particle Size Analysis (PSA) indicates a high clay content in the MS Type (Figure 5.6). PSA results could not be obtained for Zone 1 and some samples of Zone 2 as the organic carbon content was too high for the PSA procedure. In Zone 3 clay accumulates in the Orthic A horizon (0 - 300 mm, $\bar{x}$ = 71%). There is a sharp decrease of clay content in the soft plinthic B horizon (300 – 1200 mm, $\bar{x}$ = 48%). In Zone 4 clay content is much lower in the Orthic A horizon (0 – 150 mm, $\bar{x}$ = 37%). Clay appears to accumulate in the soft carbonate horizon, although it decreases again where after it reaches an average of 26% in the hard plinthic B horizon (Figure 5.3).

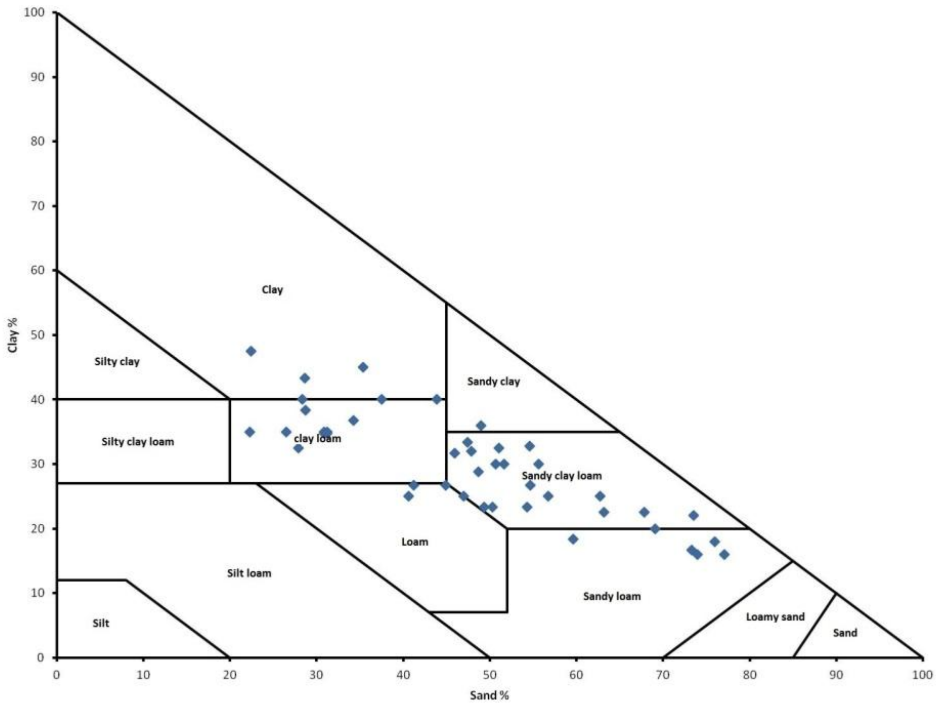

Figure 5.5. Distribution of texture classes within the MS Type.

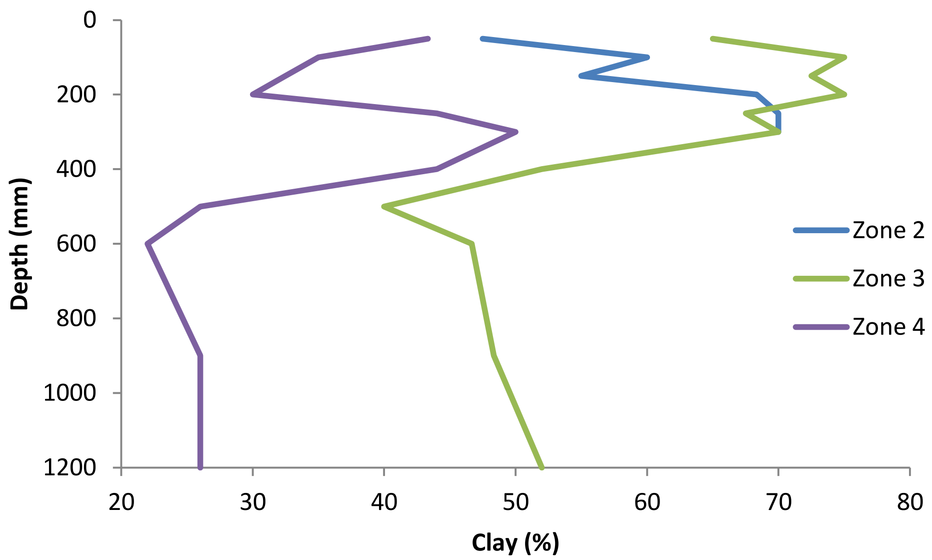

Figure 5.6. The change of clay content (%) with depth in the Muzi Swamp system; where the green line represents Zone 3, the blue line Zone 2, and the purple line Zone 4. Data was not available for all the samples.

Chemical properties

Although the Muzi Swamp is accepted as a peatland (Grundling 2014, Grundling et al. 1998) there are areas where the substrate does not have sufficient organic matter to qualify as peat (Figure 5.7). Zones 1 and 2 have similar patterns of carbon fluctuation in the top 500 mm. As depth gives an estimation of time lapse when it comes to organic matter deposition, these fluctuations indicate the changing environmental conditions under which the organic matter was deposited over time. There is a significant decrease in carbon and nitrogen between zones 1 and 2, and zone 3. Although the CEC of the topsoil of zones 1 and 2 is higher due to the association with high carbon content, it is still on the low end of the range for peaty substrates. The average CEC from both Zones 3 and 4 in the whole profile is very high, and is associated with the high pH ($\bar{x}$ = 8.9 for Zone 3 and $\bar{x}$ = 8.7 for Zone 4) and high clay content ($\bar{x}$ = 60% for Zone 3 and $\bar{x}$ = 34% for Zone 4) of these two zones (Aprile & Lorandi 2012, Saidi 2012, Helling 1964). The Ca and Na cations follow the same pattern as carbon where zones 1 and 2 are higher than zones 3 and 4, while the K and Mg cations have a more evenly distributed pattern between the zones. The Fe content in the MS Type is very high. Zone 2 has the highest Fe content ($\bar{x}$ = 9 677 $mg.kg^{-1}$), followed by Zone 1 ($\bar{x}$ = 6 957 $mg.kg^{-1}$), Zone 3 (4 588 $mg.kg^{-1}$), and Zone 4 (1 481 $mg.kg^{-1}$). Mn generally follows the same pattern except that Zone 3 has a lower content than Zone 4.

The pH of zones 1 and 2 ($\bar{x}$ = 7.1 and 7.5 respectively) is much lower than zones 3 and 4 ($\bar{x}$ = 8.9 and 8.7 respectively) due to the acidic influence of the high organic carbon content. However, these values are still very high for wetland soils. The high pH of all the zones is attributed to the high occurrence of lime in the system. Resistance is very high in especially Zone 4 ($\bar{x}$ = 2 618 Ω), and the lowest in zones 1 and 2 ($\bar{x}$ = 127 Ω and 780 Ω, respectively).

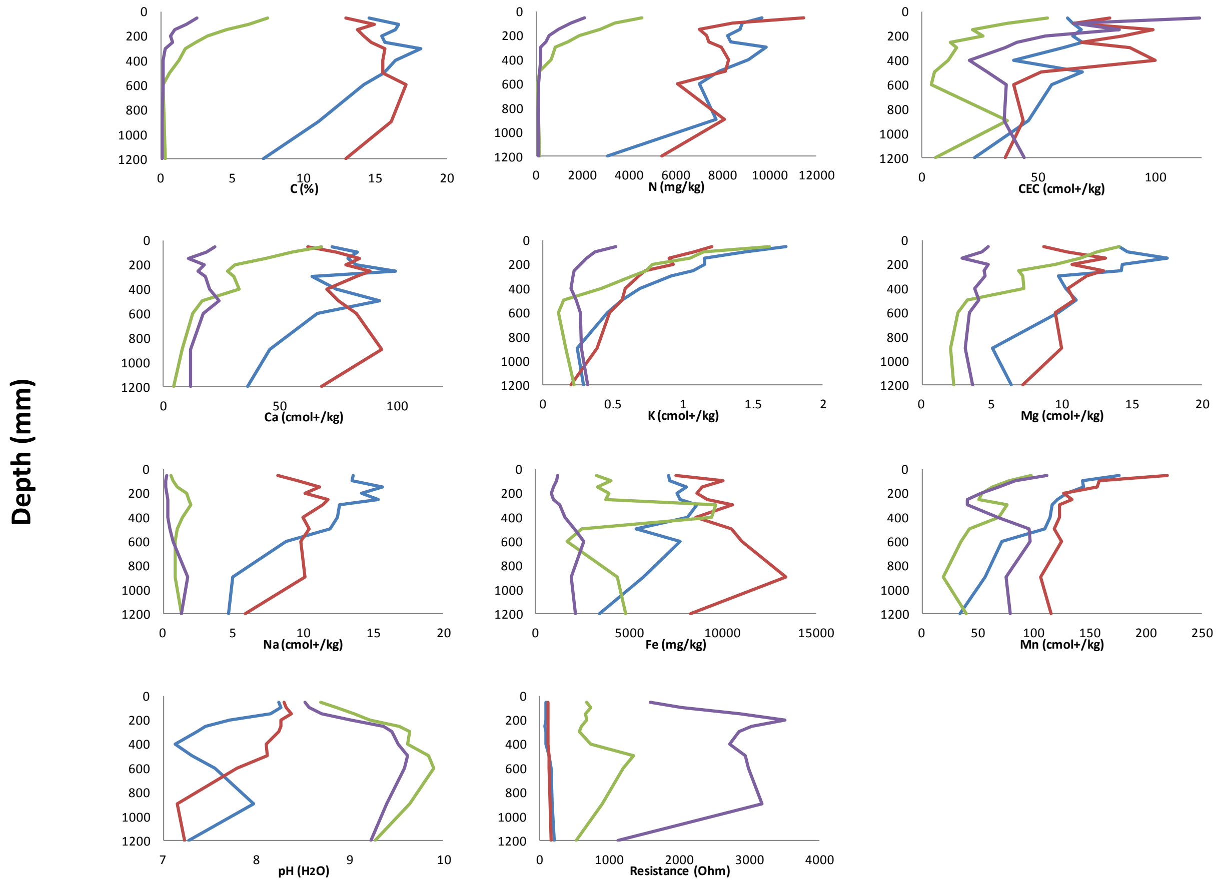

Figure 5.7. The average fluctuation of OC, Ca, CEC, Fe, K, Mg, Mn, N, Na, pH, and resistance over depth in the various wetland zones in the MS Type. Blue = Zone 1; Red = Zone 2; Green = Zone 3; and Purple = Zone 4.

5.3.2 The Tembe Park Perched Pans (PP Type)

Morphological and physical properties

During sampling saturation in the profile was reached only in the one transect of the first two zones, at a depth of 400 mm. After rainy events these pans are saturated, however. Underlying calcareous material is a source of lime in the pans, and slight effervescence with the addition of acid (10% HCl) is present in most of the profiles. Mottling is present in most of the profiles, except in one transect where mottling is absent from the Orthic A horizon. This absence may be a result of the water table present at 400 mm depth, which therefore indicates more permanently saturated conditions than the other transects. The presence of mottles throughout all the zones in the other transects is indicative of the seasonality of these pans. Mottles are generally few and red, but vary in their size and distinctiveness (Addendum A). Secondary yellow and grey mottles were often encountered.

The Orthic A horizons are coarsely structured with a hard consistence within the pans, but decrease in structure and consistency towards the outside of the pans. G horizons are expected in the pans of this flat landscape (Le Roux et al. 2013), and are strongly structured with a hard consistency. The presence of the G horizons in this landscape gives an indication of continuous wetness for a significant number of months per year (Fey 2010, Van Huyssteen et al. 2004, Soil Classification Working Group 1991). Most of the G horizons occur at 500 mm or deeper, which would result in more seasonal than permanent wetness. The prisma- and pedocutanic B horizons are regarded as duplex soils due to their marked increase in clay compared to the overlying horizon, from which it is separated by a clear or abrupt boundary (Fey 2010). The substantial increase in clay in these subsoil horizons in the upper part of the pans play an important role in the sustaining of the perched water table after rain events. According to Le Roux et al. (2013) soil with clear A/G or E/G horizon transition such as those found in the PP Type indicates vertical luviation of clay, as opposed to having a strong vertical upward water movement.

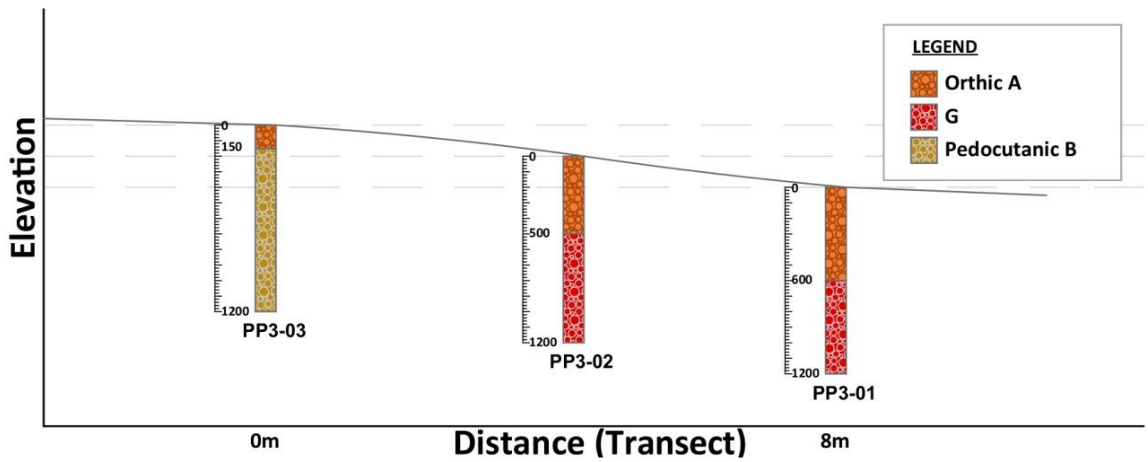

Figure 5.8. An example of a catena in the PP Type.

The majority of the samples in the PP Type falls within the loamy sand, sandy loam, and sandy clay loam texture classes, with a few samples in clay loam, and loam, and only one sample which classifies as pure clay (Figure 5.9). This is regardless of the strongly structured duplex soil forms associated with high clay content.

The variation of clay content in the PP Type is directly related to the soil forms. Zone 1 has the highest clay content in the Orthic A horizons ($\bar{x}$ = 23.0% in 0 – 300 mm), where after it decreases rapidly to an average of 16.2% in the underlying horizons (Figure 5.10). Zone 2 does not give such a clear picture, although there is also an increase of clay content from the topsoil ($\bar{x}$ =16.3%) to the subsoil ($\bar{x}$ =19.4%). Zone 3 has an approximate twofold increase in clay from the Orthic A horizons ($\bar{x}$ = 12.4%) to the underlying duplex soil horizons ($\bar{x}$ = 23.8%).

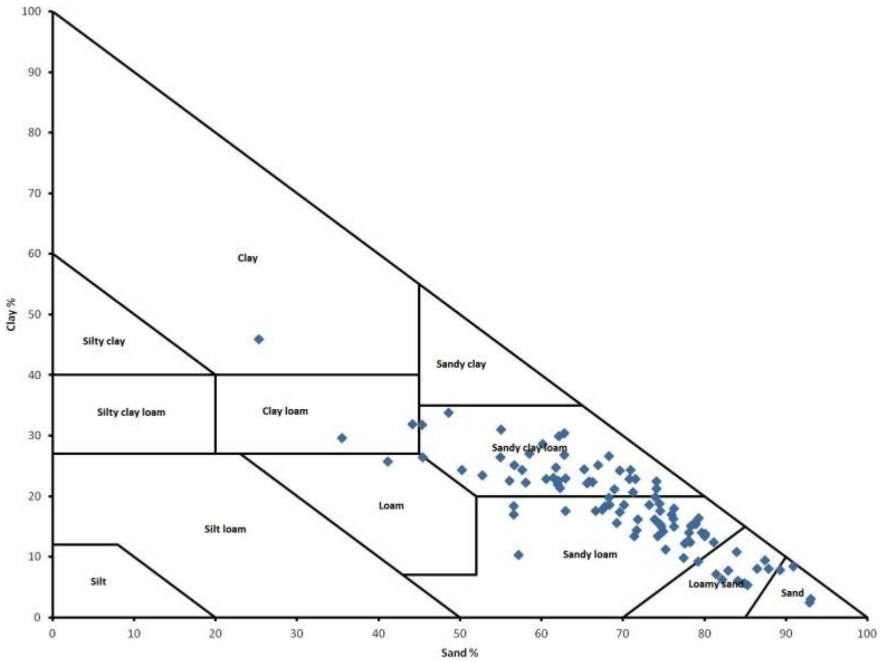

Figure 5.9. Distribution of texture classes within the PP Type.

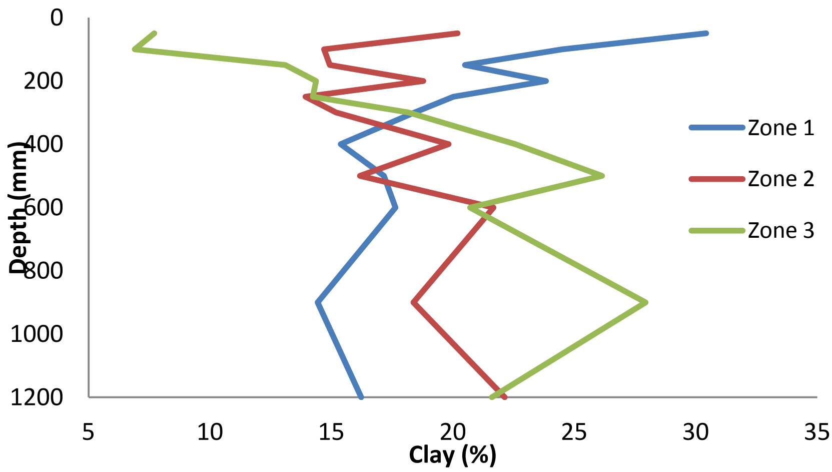

Figure 5.10. Clay content (%) across the various zones in the PP Type, where Blue = Zone 1; Red = Zone 2; and Green = Zone 3.

Chemical properties

The carbon content in the PP Type is high in comparison to soils elsewhere in South Africa (Du Preez et al. 2011), especially in Zone 1 (Figure 5.11). The carbon content is highest in the topsoil (0 – 150 mm), followed by a rapid decrease in the subsoil. This pattern is expected for duplex soils (Fey 2010). Nitrogen closely follows the same pattern. The CEC is somewhat higher than expected for sandy clay loam soils (Donahue et al. 1977), but this is probably due to the elevated pH. It would be expected that the CEC increases alongside the increase in clay and pH in the subsoil (Lambooy 2013, Aprile & Lorandi 2012, Helling 1964), however, this is not the case.

The CEC range is indicative of kaolinite clays (McLaren & Cameron 1996, Donahue et al. 1977). The Ca and K content decreases, while Na increases from the inside to the outside of the pans, and also with depth. Zone 1 has a high Fe content ($\bar{x}$ = 1 638 mg.kg^{-1}; Zone 2: $\bar{x}$ = 1 280 mg.kg^{-1}; Zone 3: $\bar{x}$ = 949 mg.kg^{-1}), probably due to more saturated conditions favouring Fe accumulation (Ponnamperuma 1972). The Fe content decreases in the subsoil. The Mn content follows a similar pattern, apart from Zone 3 which increases with depth. The pH increases steadily with depth (with an average range of 6.3 – 8.8) in a similar fashion in all three zones. This pH is high for wetland soils, and is related to the presence of both Ca and Na.

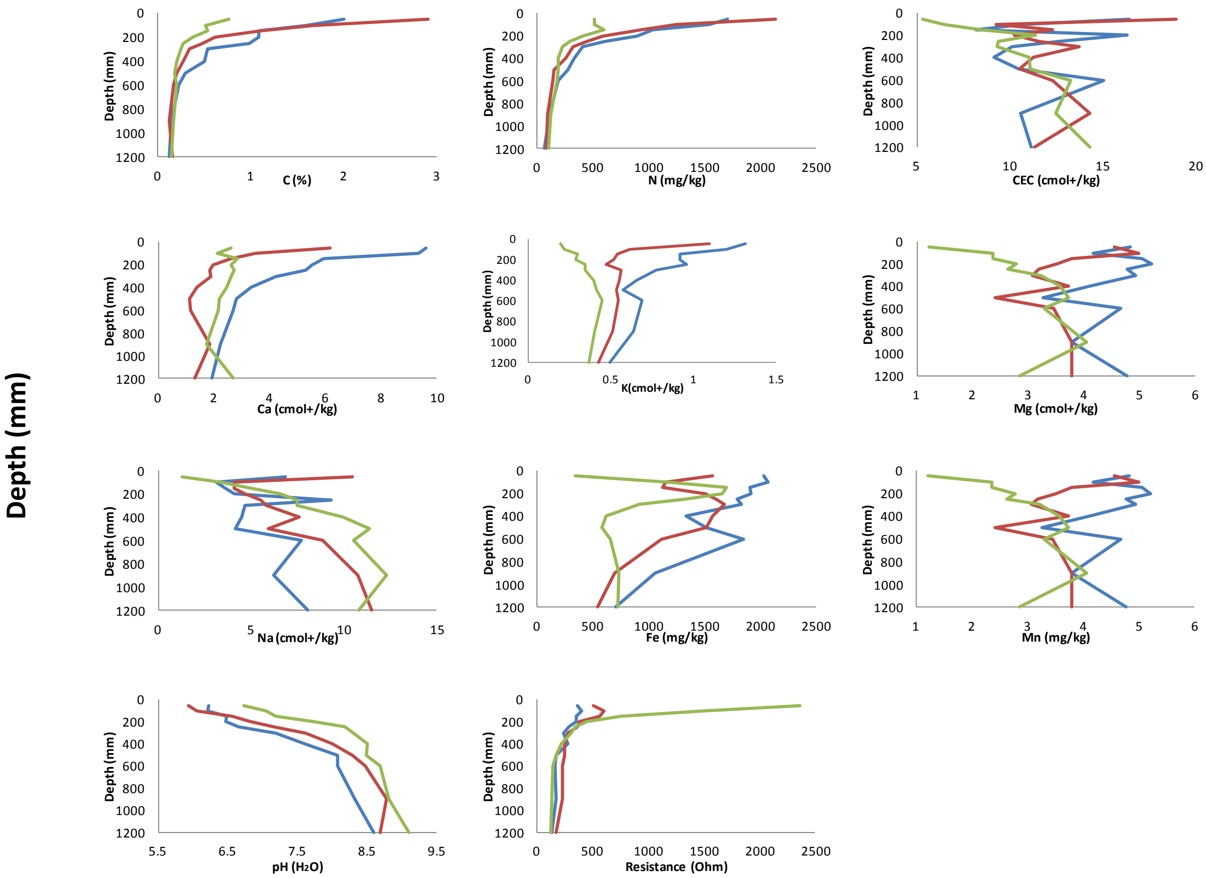

Figure 5.11. The average fluctuation of OC, Ca, CEC, Fe, K, Mg, Mn, N, Na, pH, and resistance over depth in the various wetland zones in the PP Type. Blue = Zone 1; Red = Zone 2; and Green = Zone 3.

5.3.3 The Utilised Perched Pans (DP Type)

Morphological and physical properties

The water table was not reached in any of the profiles of the Utilised Perched Pans. However, many signs of water saturation were present. Mottles are conspicuously absent from all the Orthic A horizons (except in the profile right on the crest of the dune), but are abundant in the subsoil. In the G horizon of Zones 1 - 3 mottles are many, coarsely textured, and distinctly yellow coloured. Blue-green secondary mottles were encountered in the one G horizon, which is an indication of seasonally saturated soils (Rossouw 2010). In the other horizons the mottling varies in size, colour, texture and abundance. Lime is present in many of the profiles, mostly in the carbonate-, unspecified/unconsolidated material with signs of wetness-, and duplex horizons. The lime also mostly only occurs in the upper part of the slope (zones 3 – 5). Clay and carbonate cutans are sporadically encountered in the Utilised Perched Pans. Similarly as with the Tembe Park Perched Pans, soil with clear A/G or E/G horizon transition indicates vertical luviation of clay (Le Roux et al. 2013).

There are quite a number of soil samples that classify as clay (Figure 5.15). It is notable that the samples cluster strongly to the right of the graph (indicating very little silt), and fall mostly in the sandy loam, sandy clay loam and sandy clay classes.

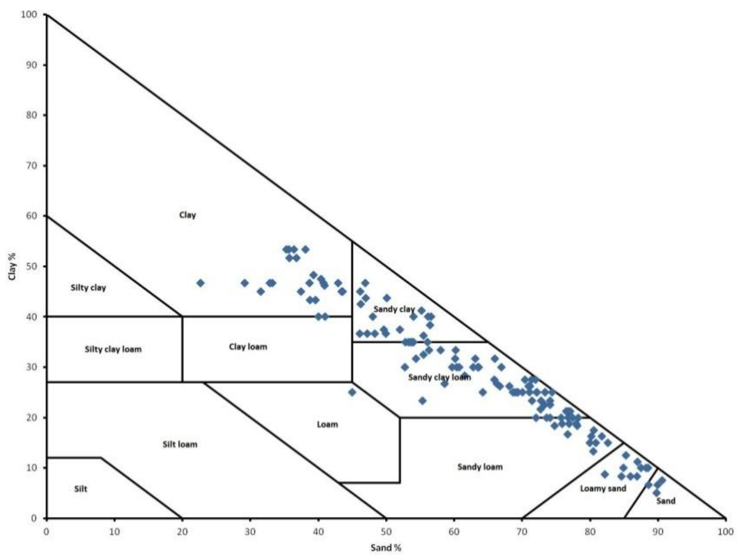

Figure 5.12. Distribution of texture classes within the DP Type.

The pans in the Utilised Perched Pans vary considerably in size, with some transects having more zones than others. Only one transect will be discussed in terms of its physical and chemical properties (Figure 5.13 and Figure 5.14).

According to Figure 5.15 Zone 2 ($\bar{x}$ = 57.9%) has more clay than Zone 1 ($\bar{x}$ = 43.5%). The reason may be attributed to the thicker G horizon (Figure 5.13). Zone 1 and 2 follows the same pattern in which the clay content decreases from the Orthic A horizon to the underlying G horizon. The decrease is gradual and not related to the horizon transitions. Zone 3 has an average of 35.9% clay which decreases from 42.1% in the Orthic A horizon, to 34.0% in the E horizon, and 23.5% in the G horizon. Zone 4 and 5 are very similar with an average clay content of 22.1% and 25.4% respectively. The clay content in both zones 4 and 5 increases with depth, in contrast to the other zones.

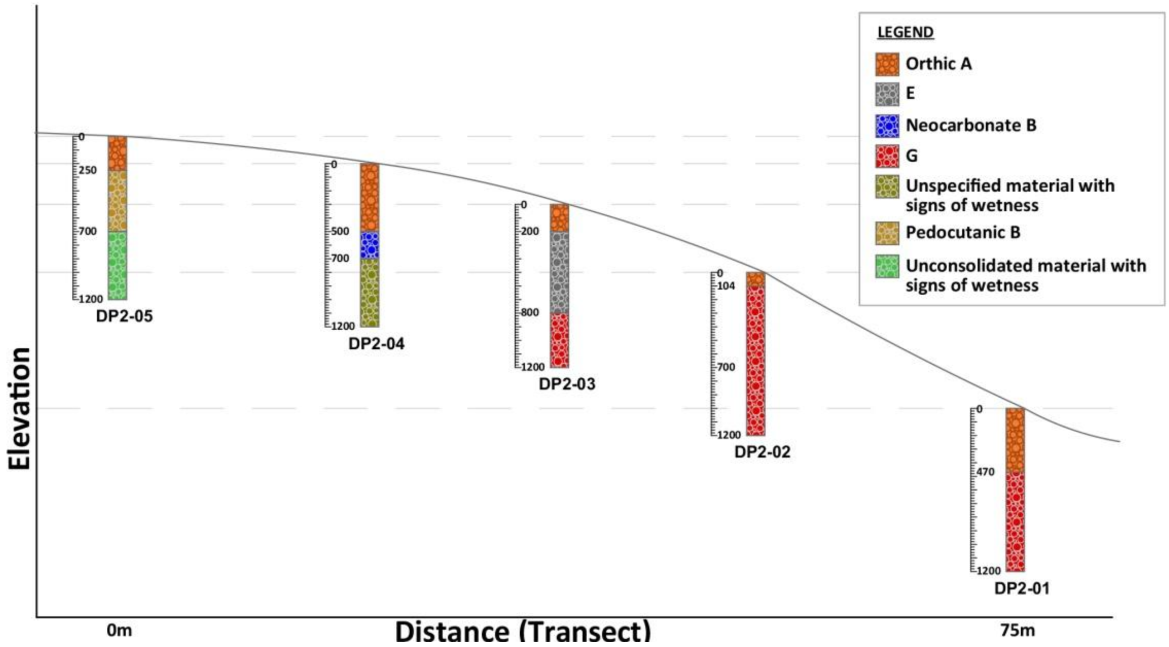

Figure 5.13. The catena in the DP Type, as discussed above.

Figure 5.14. The catena discussed above in the DP type indicating the size of the pan, and the change in slope and vegetation.

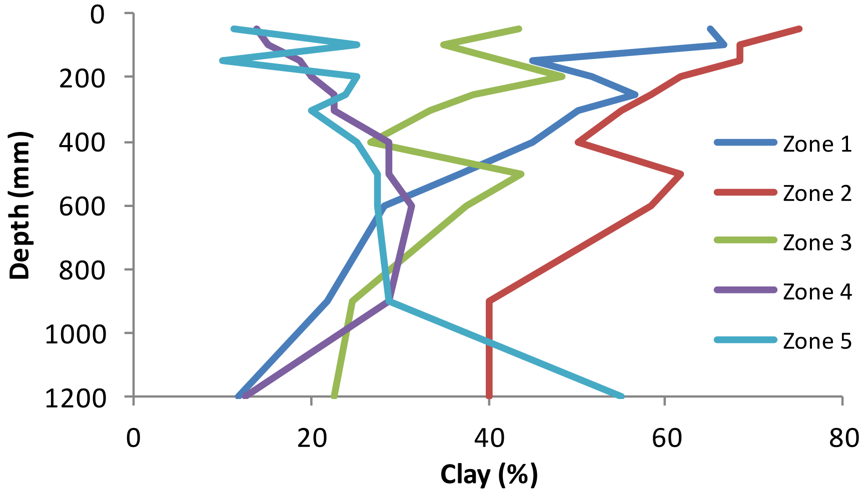

Figure 5.15. The variation of clay content amongst zones and with depth in one transect in the DP Type.

Chemical properties

As in the Tembe Park Perched Pans carbon content is relatively high in the topsoil of the first 3 zones ($\bar{x}$ = 1.97% in the top 200 mm). The carbon content in all the zones decreases rapidly from a combined average of 1.40% in the top 200 mm to 0.32% in the underlying horizons (Figure 5.16). Likewise to the clay content, zones 3 and 4 are rather similar. The carbon content of Zone 2 is higher than that of Zone 1. The CEC content is similarly very high in Zone 2. This might be as a result of the high organic matter and clay content. On the other hand, the CEC in Zones 1 and 3 is much lower although the carbon and clay content are high in these zones too. The CEC decreases with depth in zones 1 – 3, but increases with depth in zones 4 and 5.

There are three significant trends in the variation of Ca content. 1) The average Ca content in the whole profile is lower in Zone 1 ($\bar{x}$ = 4.67 $cmol_c$/kg) than in zones 2 ($\bar{x}$ = 9.63 $cmol_c$/kg) and 3 ($\bar{x}$ = 7.43 $cmol_c$ /kg). 2) Zone 4 increases from 500 mm and deeper from an average of 3.72 $cmol_c$/kg to 9.21 $cmol_c$/kg, which correlates with the transition from the Orthic A horizon to the Neocarbonate horizon. 3) Zone 4 increases from 600 mm and deeper from an average of 1.32 $cmol_c$/kg to 15.8 $cmol_c$/kg, which correlates with the transition from the Pedocutanic B horizon to the underlying unconsolidated material with signs of wetness horizon. The sharp increase in Ca in zones 3 and 4 correlates directly with the presence of lime in the wetland.

The Fe content is very high in the Utilised Perched Pans. It does not vary much between zones (from a profile average of 2 531 $mg.kg^{-1}$ in Zone 2 to a profile average of 1 122 $mg.kg^{-1}$in Zone 4), and there is no specific direction of change along the catena. The Mn content follows the same trend as Fe: very high, generally, and with Zone 2 ($\bar{x}$ = 80.2 $mg.kg^{-1}$across the profile) again being much higher than Zone 1 ($\bar{x}$ = 63.7 $mg.kg^{-1}$). The lowest Mn is Zone 4 with an average of 34.3 $mg.kg^{-1}$.

The pH varies slightly in the top 250 mm of all zones, where after it increases steadily with depth. In Zone 1 it increases from 6.5 in the topsoil to 6.5 in the subsoil; in Zone 2 from 5.9 to 7.1; in Zone 3 from 6.4 to 7.4; Zone 4 from 7.3 to 8.3; and in Zone 5 from 7.6 to 8.4. The increase of pH from the inside of the wetland to the outside is to be expected due to waterlogging after rainy events, and is increased even further due to the presence of lime in the profiles higher up on the dune. The increase with depth is due to the presence of lime deeper down in the profiles.

Resistance does not have a specific direction of change along the catena. Resistance in Zone 3 stays more or less constant with depth with a profile average of 692.7 Ω. Resistance in the other zones is elevated in the top 250 mm where after it decreases with depth. Zone 5 has the lowest resistance with a profile average of 285.5 Ω.

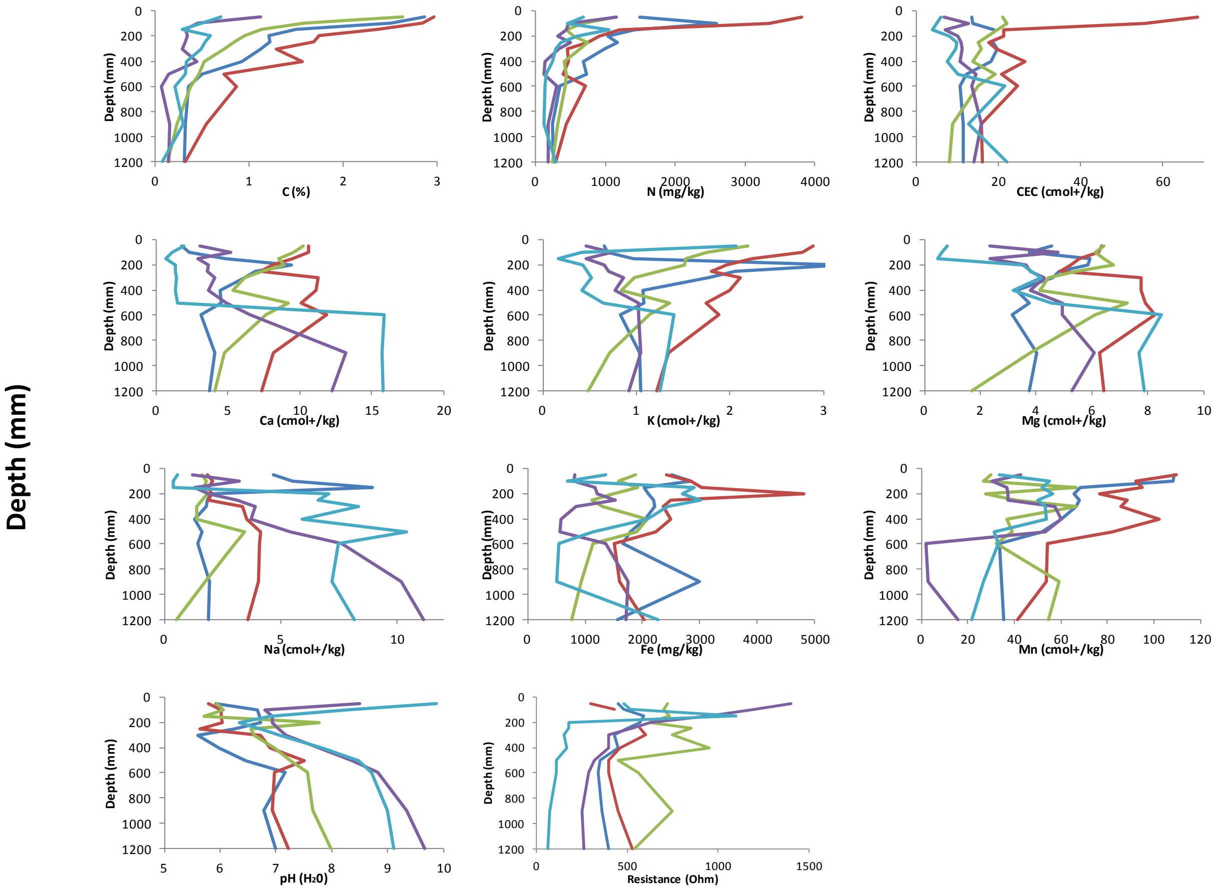

Figure 5.16. The average fluctuation of OC, Ca, CEC, Fe, K, Mg, Mn, N, Na, pH, and resistance over depth in one transect in the various wetland zones in the DP Type. Dark blue = Zone 1; Red = Zone 2; Green = Zone 3, Purple = Zone 4, and light blue = Zone 5.

5.3.4 Moist Grasslands (PL Type)

Morphological and physical properties

The Moist Grasslands wetland type is dominated by the Fernwood soil form, with an occurrence of one Champagne soil form and two Longlands soil forms (Figure 5.17). The profile morphology is very similar in all the profiles – apedal, single grain sandy soil with a loose, non-sticky and non-plastic consistency. Colour variation is the major differentiating factor: the soil profile becomes lighter with depth; and the whole profile generally becomes lighter upslope, away from the centre of the wetland. There were no coarse fragments or subsurface features visible. Although stratification was expected, this was also absent from the profiles. The water table was only reached in one of the profiles, at a depth of 1200 mm. However, Grundling et al. (2011) indicates that the water table in the wettest areas of the PL Type can be within 1 m of the soil surface. Mottles are generally absent from the A-horizon, although a few fine, red mottles was found in the A-horizon of one transect. Mottles are common in the underlying horizons – even in the zones furthest away from the centre of the wetland. These mottles of oxidized iron are few and faint. Illuvial humus was also found and formed larger and more prominent mottles.

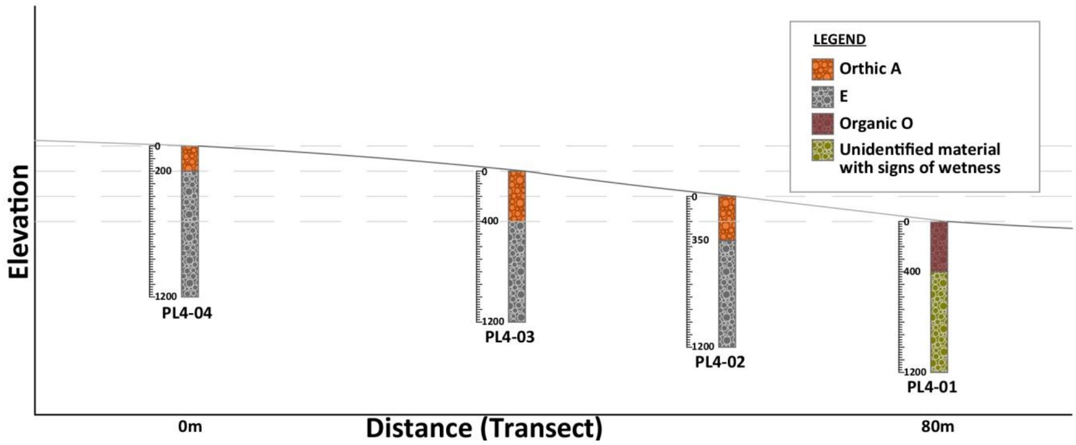

Figure 5.17. An example of a catena in the PL Type.

Figure 5.18 illustrates the extent to which the Moist Grasslands are dominated by the sand fraction. A few samples fall in the loamy sand and sandy loam classes, all of which are concentrated in the top 200 mm of two specific wetlands in the PL Type.

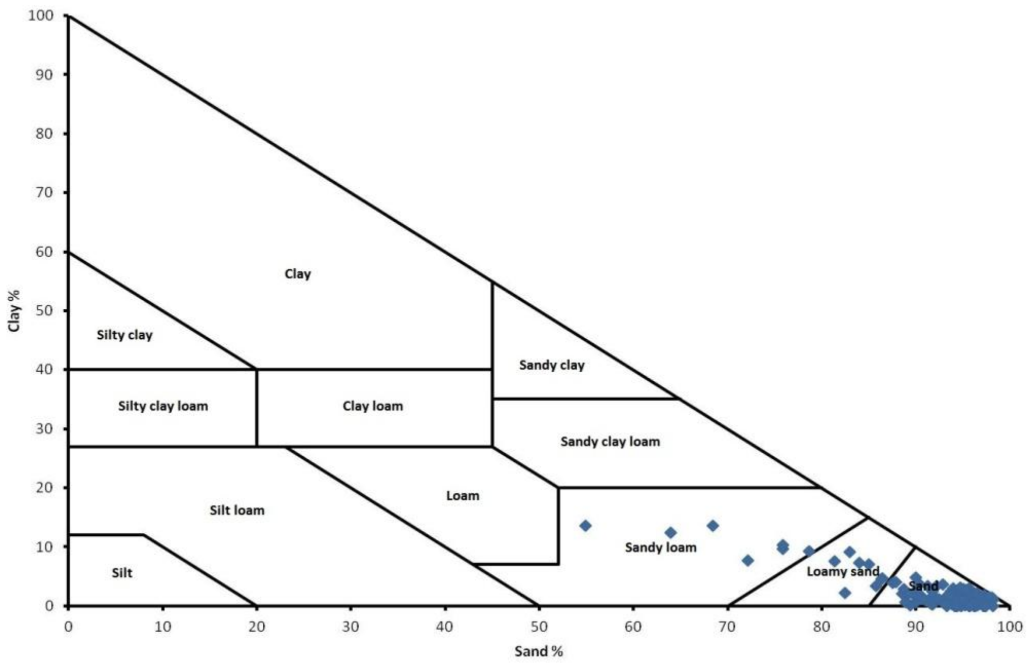

Figure 5.18. Distribution of particle size in the PL Type.

There is a good correlation value (r^2 = 0.82) between clay and carbon content (Figure 5.19). The PL Type is the only wetland type where the correlation is this high (MS Type: r^2 = 0.53; PP: r^2 = 0.03; DP: r^2 = 0.21; and IDD: r^2 = 0.45). The clay contents recorded here is generally not regarded as high (Brady & Weil 2007). Yet it appears to be high enough to increase water holding capacity and facilitate organic carbon accumulation to such an extent that as much as 14% carbon is possible on the sandy PL Type. According to Grundling et al. (2014) some areas within the Moist Grasslands (termed 'Upland area' in that study) have occurrences of high clay content (Figure 5.20).

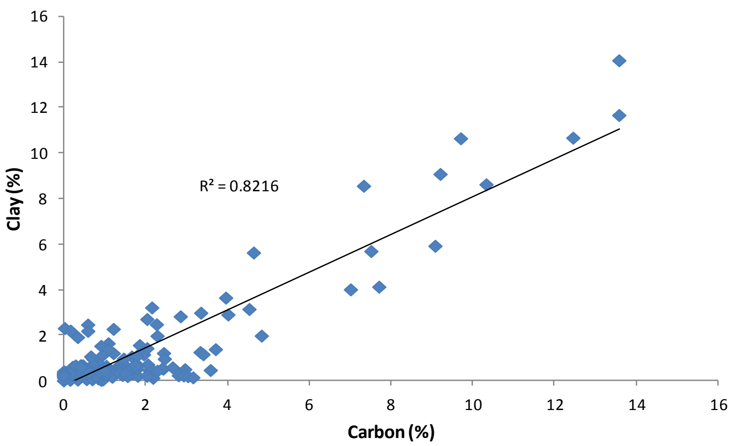

Figure 5.19. The positive correlation between carbon (%) and clay (%).

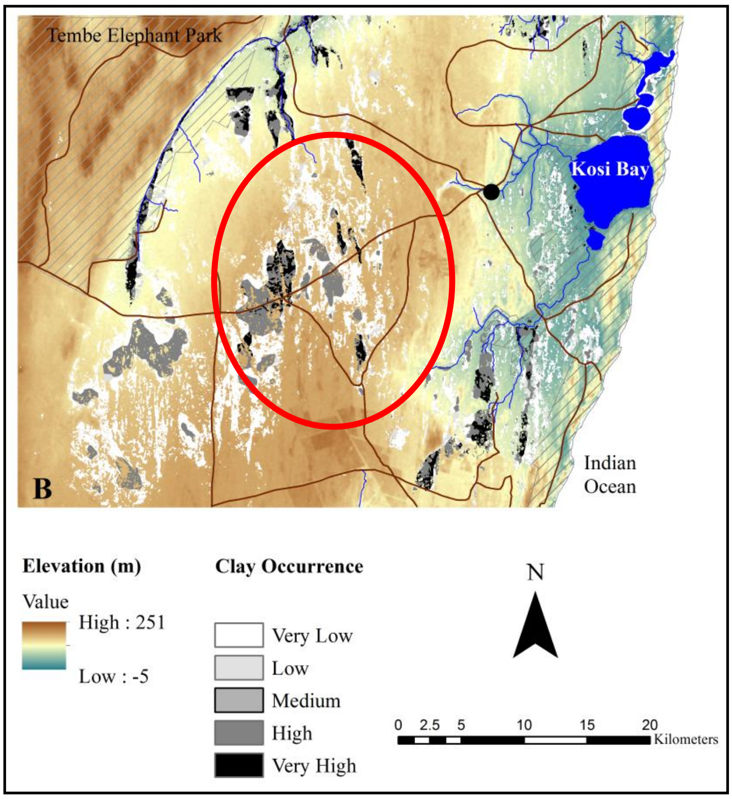

Figure 5.20. An overlay of elevation and clay occurrence (Grundling et al. 2014). The PL Type is indicated by the red oval.

Chemical properties

Figure 5.21 indicates the average chemical soil properties over depth in the various wetland zones. All chemical parameters for Zone 1 are discernibly higher than for the rest of the zones. All properties, for all zones decrease with depth, except for pH and resistance, which increase with depth. Zones 2 and 3 become rather similar at a depth of between 250 and 400 mm.

Organic carbon content in the Moist Grasslands is high, especially in Zone 1. Organic carbon content in wetlands can vary a lot, but the Moist Grasslands are characterised by sporadic floods, a deep water table, and above all, a very sandy soil profile – none of which is conducive to soil organic carbon accumulation in the soil. Even in Zone 2 the organic carbon content is high (decreasing from an average of 3.01 - 1.07% in the top 250 mm). Zone 4, which is well outside the wetland area, has an average of 1.21% in the top 50 mm. This is high for South African soils, since about 58% of soils contain less than 0.5% organic carbon and only 4% contain more than 2% organic carbon (Du Preez et al. 2011).

The CEC is generally low, which can be expected in such sandy soils. Zone 1 exhibits a higher CEC, which can be explained by the high carbon and clay content (Helling 1964). The sharp increase at the 150 mm depth is probably a sampling or analysis error. The cations Ca, K, Mg, and Na have profiles similar to carbon and CEC: very high in Zone 1 which decreases with depth, and Zones 2 – 3 with much lower contents. All cation concentrations are quite high. The high concentrations in Zone 1 can be attributed to either a loss of exchange/adsorption sites due to solubilisation of carbon and hydrous oxides of Fe and Mn, or displacement from the CEC sites due to increased concentrations of soluble Fe and Mn (Phillips & Greenway 1998). However, these reactions only take place under saturated soil conditions, which is not always the case in the Moist Grasslands.

The Fe concentration is extremely high in Zone 1 (x̄ = 20 590 $mg.kg^{-1}$ in the top 250 mm) in comparison to Zone 2 (1 511 $mg.kg^{-1}$ in the top 250 mm), Zone 3 (x̄ = 622 $mg.kg^{-1}$ in the top 250 mm), and Zone 4 (x̄ = 348 $mg.kg^{-1}$ in the top 250 mm). The Mn content follows the same trend, although Zones 2 – 4 have relatively high concentrations in the top 150 mm which decreases rapidly with depth.

Trends in pH values across the wetland zones do not present a clear pattern. The four zones have rather similar pH in the top 200 mm (ranging from 5.1 – 5.2), which loosely correlates with the depth of the Orthic A horizons. The pH does not follow a catena sequence like the other chemical properties, but does increases with depth in all zones. Although the increase of pH in acid soils depends on the activities of nitrate, iron and manganese oxides, sulphate and proton consumption during reduction of these oxidants under flooded conditions, the soil is neither saturated nor do these oxidants increase with depth as does pH. These elements may be contributed through capillary rise from the groundwater table.

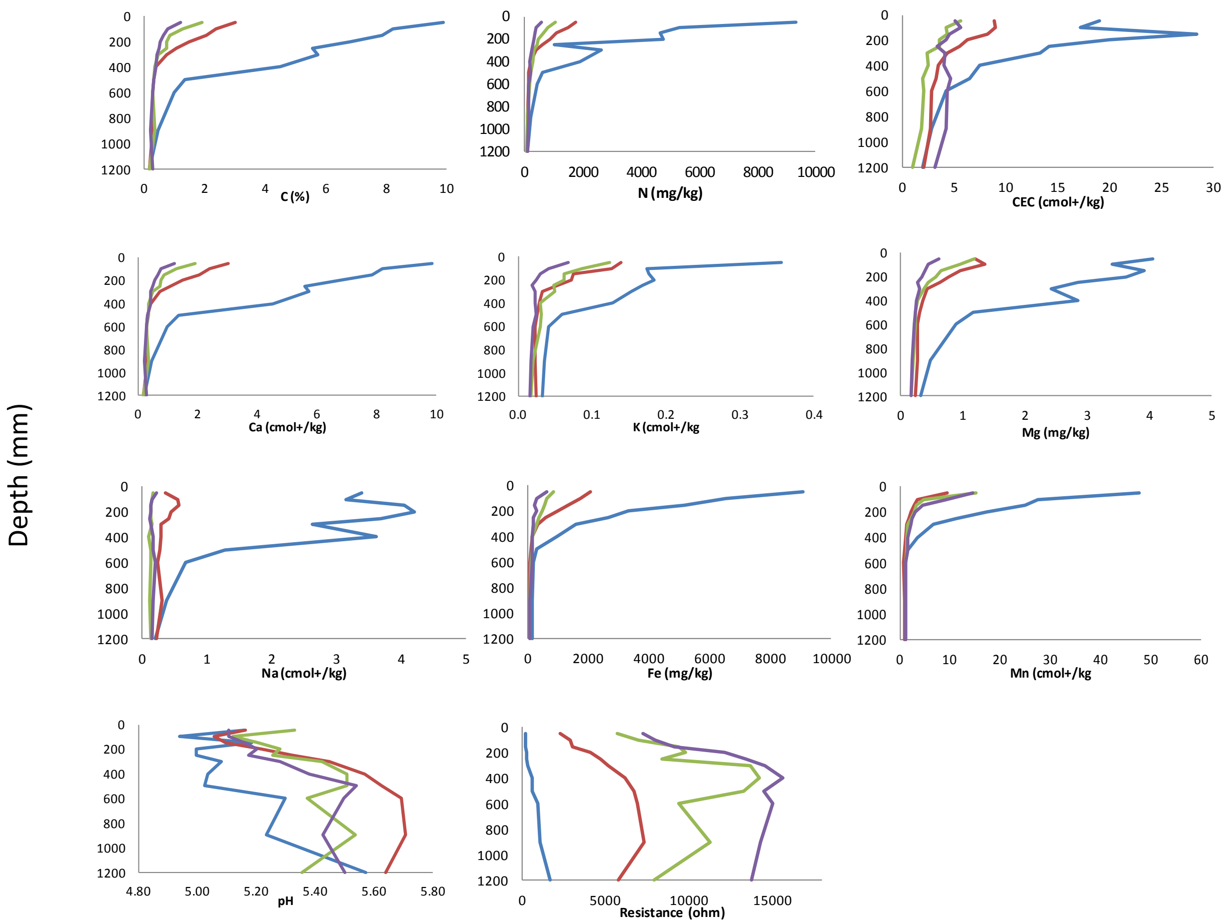

Figure 5.21. The average fluctuation of OC, Ca, CEC, Fe, K, Mg, Mn, N, Na, pH, and resistance over depth in the various wetland zones in the PL Type. Blue = Zone 1; Red = Zone 2; Green = Zone 3; and Purple = Zone 4.

5.3.5 Interdunal Depressions (IDD Type)

Morphological and physical properties

The water tables in Zones 1 and 2 were above the soil surface in all transects. As sampling was done in winter this gives an indication of the permanence of saturated conditions. The water table ranged from 20 mm to 600 mm above the surface. In Zone 3 the water table varied between 400 mm and 700 mm below surface. In Zone 4 the water table was not reached at all. Mottles were only encountered in one of the Organic O horizons, and in some of the C horizons. Mottles varied in abundance, were fine to medium in size, and distinctly coloured – usually yellow or orange. In the one Regic sand horizon mottles were few, coarse, distinct and of grey and white colour.

The profile morphology is similar in all transects. The first two zones are characterised by high organic matter substrate, and are permanently saturated (Figure 5.22). Most of the organic O horizons qualify as peat. The third zone is a transition zone between the wetland and the upland dune substrate (Pretorius 2011). Although these profiles are Namib soil forms (similar to Zone 4), the water table is still relatively high and therefore influences the soil properties. Zone 4 is on the dune crest and well outside the wetland boundaries. The morphology is apedal, single grain (or massive in Zones 1 and 2), sandy soil with a loose, non-sticky and non-plastic consistency. There are no coarse fragments or subsurface features present. There is no cementation, and stratification is absent.

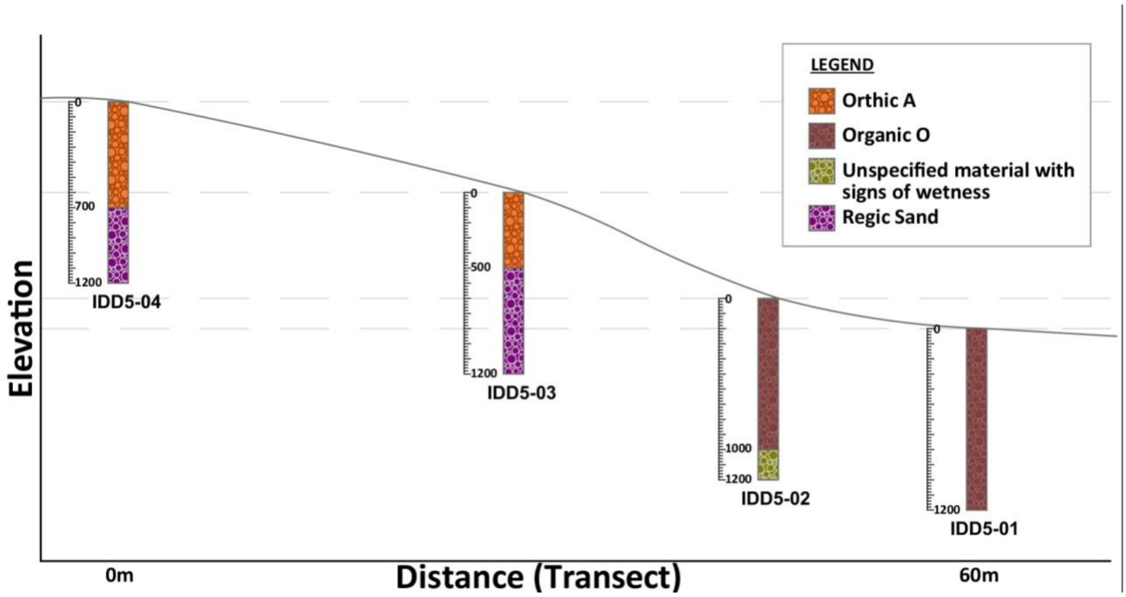

Figure 5.22. An example of a catena in the IDD Type.

All the samples are all located in the sand and loamy sand textural classes, with only three samples in the sandy loam class. This wetland type is therefore characterised by sandy and organic substrates. Figure 5.23 indicates that clay content is the highest in Zone 1 (profile average of 17.5%). The clay content in the topsoil of Zone 2 is high as well ($\bar{x}$ = 20.8 in 0 – 300 mm), but it decreases rapidly in the subsoil ($\bar{x}$ = 7.9% in 300 – 1200 mm). Particle Size Analysis (PSA) data was not available for the top four depth increments due to the difficulty in removing organic matter from high organic substrates in the PSA procedure. The variation in clay content in these two zones may correlate with environmental changes during which the organic matter was deposited. The clay content in Zone 3 decreases with depth, from an average of 10.7% in the top 300 mm to an average of 7.3% in the underlying soil. The clay content in Zone 4 increases with depth, from an average of 6.4% in the top 300 mm to an average of 8.7% in the underlying soil. The clay in Zones 1 and 2 is probably due to luviation. It is unclear where the clay in Zone 4 the dune crest originates from, although anecdotal evidence suggests that these dunes are underlain by calcrete geology, which may account for the increase in clay with depth.

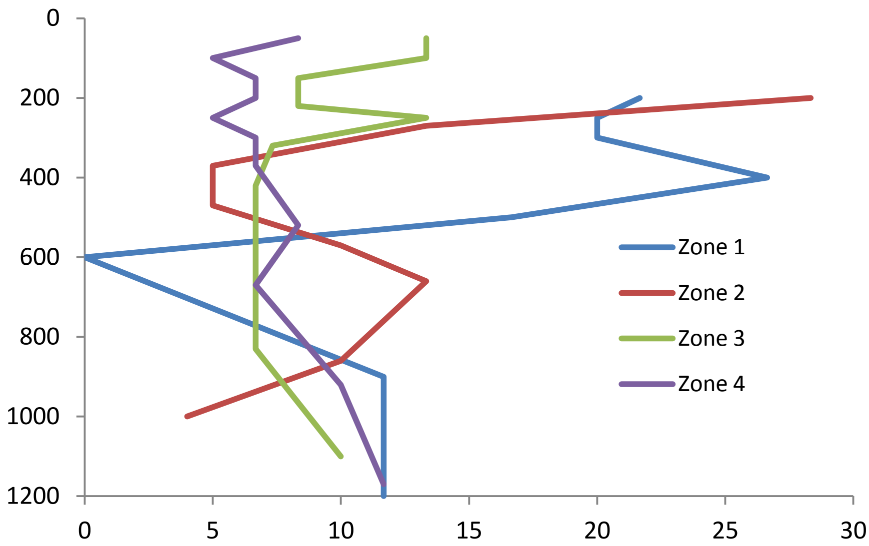

Figure 5.23. The variation of clay content amongst zones and with depth in one transect in the IDD Type. Blue = Zone 1; Red = Zone 2; Green = Zone 3; Purple = Zone 4.

Chemical properties

Zones 1 and 2 are similar in terms of the OC-, N-, Na-, Mg-, and Fe content, as well as for CEC (Figure 5.24). This is all probably due to the high organic carbon content in these zones. Although the carbon in some of the profiles was above 20% and therefore classified as peat (Addendum B), the average carbon in zones 1 and 2 fluctuate from 16.7% to 11.8% (Zone 1) and 14.2% to 9.1% (Zone 2), in the top 200 mm and in the underlying soil, respectively. In one of the transects the Organic O horizon is very thin and underlain by unspecified material with signs of wetness. Therefore, although the morphology of the IDD Type is quite similar in all of the wetlands, there are many factors, such as organic carbon accumulation, influencing the dynamics of the wetlands. The organic carbon content decreases from 2.1% to 1.1% (Zone 3) and 0.7% to 0.5% (Zone 4), in the top 200 mm and in the underlying soil, respectively. Nitrogen content follows the same trend as carbon content.

The CEC is low for Organic O horizons (Helling 1964), and is probably a result of the low pH in this wetland type. The CEC decreases from 34.3 $cmol_+$/kg to 14.0 $cmol_+$/kg (Zone 1); 35.6 $cmol_+$/kg to 8.6 $cmol_+$/kg (Zone 2); 5.4 $cmo_{l+/}$kg to 2.2 $cmol_+$/kg (Zone 3) and 2.3 $cmol_+$/kg to 1.3 $cmol_+$/kg (Zone 4) in the top 300 mm and in the underlying soil, respectively. All the cations except for K also follow this pattern, although there is quite a difference between Zones 1 and 2 in terms of Ca.

Zone 1 has a high average profile Fe content of 1 297 $mg.kg^{-1}$, but there is a sharp decrease at 250 mm from 2 231 $mg.kg^{-1}$ to 518 $mg.kg^{-1}$ in the subsoil. The Fe content is higher in Zone 4

($\bar{x}$ = 208 mg.kg^{-1}) than in Zone 3 ($\bar{x}$ = 119 mg.kg^{-1}), which is unexpected. Zone 4 has the highest Mn content of all the zones ($\bar{x}$ = 9.55 mg.kg^{-1}), followed by Zone 1 ($\bar{x}$ = 7.42 mg.kg^{-1}), Zone 3 ($\bar{x}$ = 4.82 mg.kg^{-1}), and then Zone 2 ($\bar{x}$ = 2.86 mg.kg^{-1}).

The organic substrate is even more acidic than the leached sandy soils upslope. The pH generally decreases with depth, but Zone 2, with the lowest pH in the topsoil, increases with depth. Resistance is very high and similar in Zones 3 and 4 ($\bar{x}$ = 11 426 Ω), and the lowest in Zone 1 ($\bar{x}$ = 972 Ω).

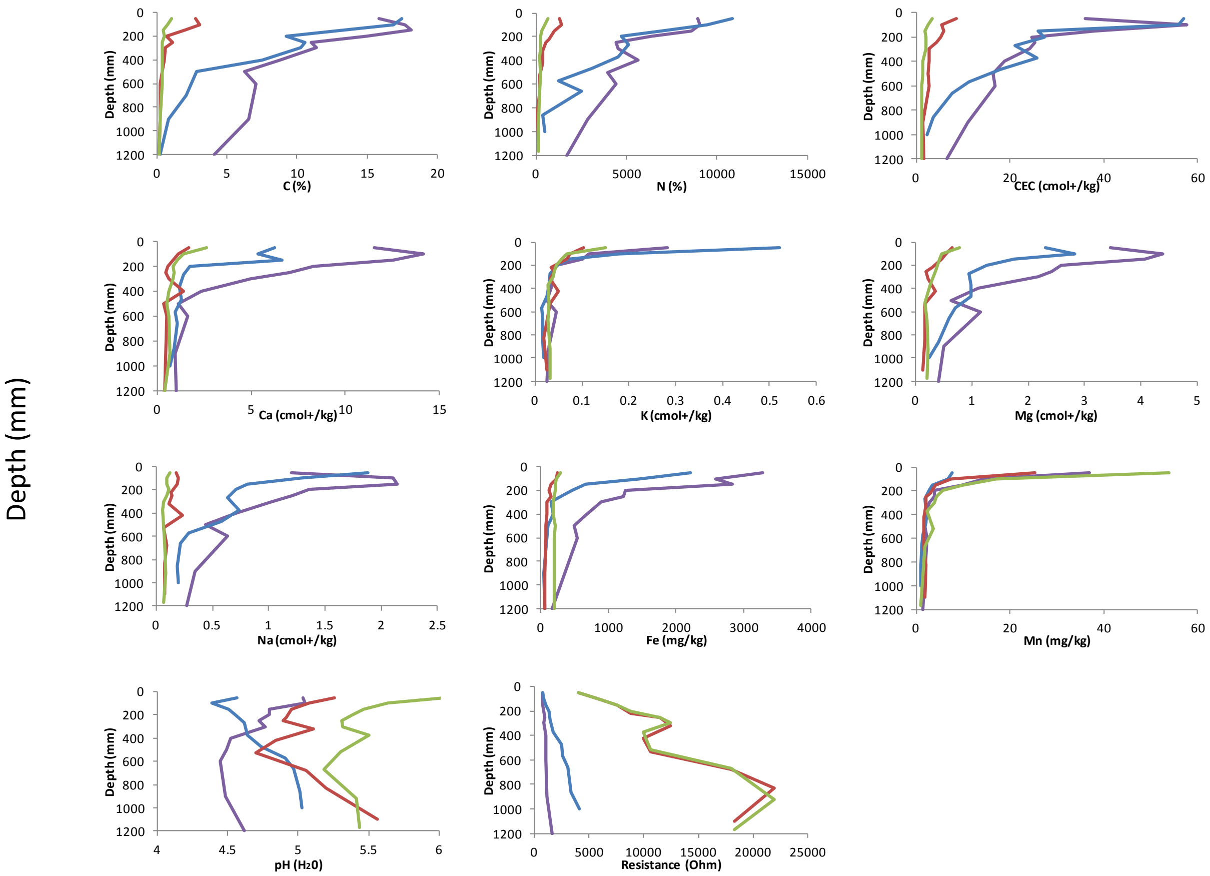

Figure 5.24. The average fluctuation of OC, Ca, CEC, Fe, K, Mg, Mn, N, Na, pH, and resistance over depth in the various wetland zones in the IDD Type. Purple = Zone 1; Blue = Zone 2; Red = Zone 3; and Green = Zone 4.

5.4 Discussion

The distribution of soil forms gives an indication of the main characteristics of the various wetland types, according to which the wetland types can be described (Table 5.3). Most obvious is the Champagne soil forms in the Muzi Swamp-, Interdunal Depression-, and Moist Grasslands wetland types, which indicate that the wetlands are organic in nature. Similarly soil forms such as Katspruit, Sterkspruit, Kroonstad, Sepane and Valsrivier are indicative of clay systems. The presence of lime on the MCP is associated with the clay systems, and therefore soil forms such as Brandvlei, Montagu and Kinkelbos would also be indicative of a clay system. The dominance of Fernwood and Namib soil forms in the Moist Grasslands and Interdunal Depression wetland types indicates that these are sandy wetland types (or at least that certain zones of the wetlands are sandy).

Table 5.3. The distribution of the wetland types and zones among the three major substrate classes.

Type	Organic soils		Clay soils		Sandy soils	
	Zones	Soil forms	Zones	Soil forms	Zones	Soil forms
MS	1, 2	Champagne	3, 4	Westleigh, Longlands, Katspruit, Brandvlei, Montagu, Kinkelbos, Sterkspruit, Valsrivier, Sepane,	-	
PP	-		1, 2, 3		-	
DP	-		1, 2, 3		-	
PL	1	Champagne	-		1, 2, 3, 4	Fernwood, Longlands
IDD	1, 2		-		3, 4	Fernwood, Namib

5.4.1 Organic soil

Organic soils are present in three of the wetland types on the MCP:

1) The Muzi Swamp is a long, linear, calcareous mire located in a valley bottom. Two of its four zones are characterised by high organic carbon content. It is regarded as a eutrophic (rich) fen.
2) The Interdunal Depression Type is characterised by wetlands located in deep depressions enclosed by dune fields. These wetlands are driven by groundwater input, and generally have a substrate high in organic matter. It is regarded as an oligotrophic (poor) fen.
3) Zone 1 of the Moist Grasslands (in the PL Type wetlands which occur in the central portion of the whole elevated upland area (refer to Section **Error! Reference source not found.**)) is haracterized by an unusually high organic carbon content.

The presence of high organic carbon content on the MCP is linked to the high groundwater table, resulting in supposedly permanent saturation of these horizons. The area is currently in the grip of a long term drought period (Grundling et al. 2014), and the water table in these profiles are therefore well below the required level to maintain these high organic carbon horizons. Currently only the IDD Type has a water table at the surface. Not all of these profiles have high organic carbon content throughout the whole profile. Organic carbon content in the top 200 mm (the depth over which an Organic O is classified (Soil Classification Working Group 1991)) range from an average of 15.5% in the IDD Type, 14.9% in the MS Type, and 11.8% in the PL Type.

There is an accumulation of clay in the pans and valley bottom wetlands, probably due to luviation processes. It is commonly accepted that clayey soils accumulate organic carbon more efficiently than sandy soils, because clayey soils with a high surface area have a higher humification efficiency than coarse-textured soils (Lal 2007, Krull et al. 2001, Baldock and Skjemstad 2000). The physical protection of organic carbon is a factor of soil texture, specific mineral surface area and soil mineralogy, also affected by factors such as water-holding capacity, pH and porosity (Lal 2007, Zinn et al. 2005, Krull et al. 2001, Baldock and Skjemstad 2000). However, according to Zinn (2005) sandy soils may, or may not, contain less organic carbon than fine-textured soil, depending on a number of factors, and it is imperative to carry out studies on how texture affects organic carbon under South African conditions (Nciizah & Wakindiki 2012). It is evident that this is the case on the MCP, as it is only in the Moist Grasslands where there is a direct correlation between carbon- and clay content. The Moist Grasslands is an expansive, flat area located on a higher elevation than the rest of the wetland types, and acts as a recharge area for the regional groundwater table (Grundling et al. 2014, Pretorius 2011). It is characterised by slight depressions in between sporadic ridges colonized by Lala Palms (*Hyphaene coriacea*) which accumulate water, colloidal material, and soil organic carbon. The PL Type is not as freely drained as the apedal, sandy profiles would suggest at first glance. According to Grundling (2014) a partial aquiclude with silty sand and high clay content is formed where these depressions directly overlay the Kosi Bay Formation (Figure 5.20). Here the depth to the water table is generally less than 3 m. Four transects were sampled in the Moist Grasslands. Two of these transects occur more or less in the middle of this extensive upland area (close to the watershed where the water table is at its highest), while the other two transects occur on the western and eastern outer extreme edges of the upland area, respectively (Figure 5.25). These last two transects are much drier and more seasonal. The Moist Grasslands is linked to the groundwater table, and although most of the area is currently dry and driven by sporadic flood events, certain patches (including the innermost two transects in this study) has a high watertable for most of the year, (and can therefore be regarded as permanently wet (Grundling et al. 2014)), and has an unusually high carbon content. This also elucidates the significantly high values of all properties in Zone 1 of the PL Type.

a) b)

Figure 5.25. An illustration of the differences between (a) the transects in the middle of the PL Type, and (b) the transects on the western edge of the PL Type. (a) is significantly wetter than (b) due to a higher clay content and closer proximity to the water table.

The largest part of the Moist Grasslands is seasonally/temporarily flooded. However, organic matter accumulates in certain areas in this wetland type due to close proximity of the water table. This is postulated to be a result of a number of factors: a decrease in soil particle size with depth and an increase in density in the sandy subsoil (Grundling et al. 2014), a higher clay content (Section 5.3.4, Grundling et al. 2014), and/or the possible effect of plant organic compound exudes that change the water affinity of organic compounds (Fourie et al. Undated). The source, and therefore the composition of the water, may also attribute to the carbon accumulation, as the Moist Grasslands wetland type is driven by groundwater and not rainwater like the clay-enriched systems. The chemical composition of groundwater, such as oxygen content, must be such that organic matter decomposition is further retarded than when rainwater is the main water source. Additionally, the clay content in the Moist Grasslands wetland type is high enough to increase water holding capacity and facilitate organic carbon accumulation, but not high enough to create completely perched conditions where the groundwater source is separated from the topsoil.

5.4.2 Clay soil

The Muzi Swamp (MS Type)

The Muzi Swamp has the most variation in terms of morphological, physical, and chemical characteristics, even within similar wetness zones. Pretorius et al. (2014) found similar variation in the investigation in vegetation composition on the Muzi Swamp. This large variation is due to a more complex combination of clay, organic matter accumulation, and calcrete than in the other systems. It is also a result of the type of system: the quality and through flow (and the resulting chemical transformations) of water in a peatland has a strong influence on the chemistry of the system. Because the Muzi Swamp is a linear system with water moving through the peatland, the dynamics are much more complex.

The Muzi Swamp has high organic soils and peat within the peatland area, and seasonal calcimorphic, duplex soil on the edge of the linear system. The clay content in the Muzi Swamp is by far the highest of all the wetland types. This, as well as the calcium carbonate presence, is due to the contact with the Uloa/Umkwelane Formation. Lateral ground water movement through and over this formation has resulted in the formation of the clayey, calcareous, duplex soils adjacent to the Muzi Swamp, as well as the high clay and calcium carbonate contents within the peat body.

The Tembe Park- and Utilized Perched Pans (PP- and DP Type)

The Tembe Park- and the Utilised Perched Pans occur as a series of clay-enriched pans occurring at a slightly higher elevation west of the linear Muzi Swamp. These seasonal pans have a perched water table, and are therefore only saturated for a few months per year. The Tembe Park Perched Pans occurs within the Tembe Elephant Park. The Utilised Perched Pans occurs somewhat more to the south outside the Park (still west of the Muzi Swamp), and thus has anthropological influences such as grazing pressure, fire, and clearing of the natural vegetation surrounding the pans for better water access and firewood. Pretorius et al. (2014) hypothesised that the Tembe Park Perched Pans and the Utilised Perched Pans is in fact one and the same wetland type, with the differences between the types being attributed to anthropological influence. However, in addition to the differences in vegetation composition between the two types, the investigation of the soil profiles provides evidence to support the theory that the Utilised Perched Pans are saturated for a longer period than the Tembe Park Perched Pans. Firstly, the G horizons in the Utilised Perched Pans are close to the surface, resulting in a prolonged wetness period during the year (Fey 2010). Secondly, the zone on the dune crest of the Utilised Perched Pans is characterised by the Sepane soil form, which has signs of wetness below the pedocutanic B horizon. This is in contrast to the Tembe Park Perched Pans, which is characterized by the Valsrivier soil form in the same catena position. This implies that the Utilised Perched Pans still have water movement in the profile with the possibility of becoming saturated, even on the crest surrounding the pan, while the Tembe Park Perched Pans pan is dry on the crest. Lastly, the Utilised Perched Pans has much better development of Plinthic horizons which are indicative of wet conditions.

The presence of the prisma- and pedocutanc B horizons in both types implies a much older environmental setting (Fey 2010). According to Matthews et al. (2001) these soil forms form as a result of vertical and lateral movement of water towards the lower-lying Muzi Swamp to the east. The neocarbonate horizons in the Utilised Perched Pans and the presence of calcium carbonate in both types are a result of the presence of underlying calcrete material (Grundling 2014, Matthews et al. 2001) Outcrops of this material from the Uloa/Umkwelane Formation can be seen in areas surrounding the Utilised Perched Pans where it is being mined for road building material. The neocarbonate horizons probably developed due to limited drainage in the pans (Le Roux et al. 2013). The influence of the underlying calcrete material is more pronounced in the Utilised Perched Pans than in the Tembe Park Perched Pans; evident in the presence of developed calcic horizons in the Utilised Perched Pans and the absence thereof in the Tembe Park Perched Pans. Figure 5.9, Figure 5.10, Figure 5.15 indicate that the Utilised Perched Pans has significantly more clay than the Tembe Park Perched Pans.

The morphology of the Utilised Perched Pans (in terms of its clay content and presence of calcic and plinthic horizons) is in fact more similar to the clay-enriched edges of the Muzi Swamp than it is to the Tembe Park Perched Pans. However, in terms of CEC the Utilised Perched Pans and Tembe Park Perched Pans are more similar. The clay zones of the Muzi Swamp, with an average of 36.0 $cmol_+/kg$ for the whole system, is much higher than the Utilised Perched Pans (16.0 $cmol_+/kg$) and the Tembe Park Perched Pans (11.5 $cmol_+/kg$), due to the influence of the high organic matter and higher pH (MS Type: $\bar{x}$ = 8.8; DP Type: $\bar{x}$ = 7.6; and PP Type: $\bar{x}$ = 7.6). The pH of all three wetland types increases with depth in the clay-enriched horizons due to the presence of Ca and Na deeper in the profile.

Fe content is extremely high in the clay zones of the Muzi Swamp ($\bar{x}$ =3 035 $mg.kg^{-1}$). This is followed by the Utilised Perched Pans ($\bar{x}$ = 2 280 $mg.kg^{-1}$), and then the Tembe Park Perched Pans ($\bar{x}$ = 1 279 $mg.kg^{-1}$).

5.4.3 Sandy soil

The mottling encountered in the Moist Grasslands requires special attention. According to DWAF (2005), the sandy coastal aquifers do not necessarily exhibit hydromorphic features such as mottles. Most profiles in the Moist Grasslands did, however, have few fine mottles in the subsoil. Mottling was also not restricted to a specific zone, as is prescribed by wetland delineation theory (DWAF 2005). This may be because the whole flat upland PL Type area is regarded as a recharge area characterised by occasional flooding. One of the transects exhibited no mottling at all. According to Mabuza (2013) the limiting factor is the amount of iron and manganese *oxides* present. Although these oxides are able to form redoximorphic features, it is reduced soon after oxidation and therefore cannot leave the hydromorphic signatures in the soil. This is consistent to what was observed in the field during this study – that mottling can appear and disappear rather quickly following rain events. Sandy soil reduces faster, but also oxidizes faster than clay soils. Vepraskas & Wilding (1983) substantiates this with a study that showed that in some soils with small pores reducing conditions prevailed for longer than the duration of saturation, and vice versa for soils with large pores, and similarly Vepraskas (2001) states that acidic soils high in organic matter may exhibit iron reduction as rapidly as one week following saturation. According to Kotze et al. (1996) the relationship between the frequency and duration of saturation and the particular hydric soils and vegetation that develop as a result of saturation is poorly understood. On the sandy wetland types of the MCP it can therefore be concluded that the accepted soil theory that mottles are a dependable hydromorphic feature because it is preserved in the soil (Richardson & Vepraskas 2001) is therefore not valid, especially in sandy soil.

The Interdunal Depression wetland type is characterised by wetlands located in deep depressions enclosed by dune fields. Zones 3 and 4 of this wetland type is very similar to the Moist Grasslands (Pretorius et al. 2014), in terms of its aeolian and alluvial origin, resulting in apedal, single grain sandy soil with a loose, non-sticky and non-plastic consistency. Colour variation is the major varying morphological character, and there are no coarse fragments or subsurface features present.

There are two major differences between the sandy horizons of these two wetland types. Firstly, the steep slope of the Interdunal Depression dunes will probably never result in this wetland type being saturated to the crest of the surrounding dunes. The Moist Grasslands, on the other hand, may be flooded in all four zones due to its flat topography. This is evident in the presence of mottles, which are more abundant in the subsoil of the Moist Grasslands than in the Interdunal Depressions. These mottles are, however, not a very reliant indicator, due to the temporary nature thereof. Secondly, the subsoil of the Moist Grasslands mostly consists of E-horizons, in contrast to the Interdunal Depressions which is underlain by regic sand. This indicates that the profiles in the Moist Grasslands are pedogenically more developed and reworked, and probably older than the dunes amongst which the Interdunal Depressions occur. These dunes were deposited during multiple sea-level fluctuations in the Tertiary Period and it therefore follows that the dunes of the Interdunal Depressions would be younger in the east than the flat Moist Grasslands in the west.

The maximum clay content in the sandy horizons of both the Interdunal Depressions and Moist Grasslands is very similar (not including Zone 1 which classify as a high organic horizon). The range of clay content in the Interdunal Depressions is, however, much wider. The clay content of the Moist Grasslands ranges from 0.26% to 15%, and the Interdunal Depressions 5% to 13.3%. The minimum of 5% on the dune crest of the Interdunal Depressions is unexpected, and the reason thereof unknown. These values are in stark contrast to the clay contents encountered in the clay-enriched wetlands (PP-, DP-, and edges of the MS Types).

The carbon content as well as the pH values is very similar in the sandy horizons of the two systems (with an overall average of 0.76% and 0.74% carbon in the Moist Grasslands and Interdunal Depressions, respectively; and a pH of 5.4 and 5.3 in the PL- and IDD Type, respectively). The CEC is, however, somewhat higher in the IDD Type (4.12 $cmol_+/kg$) compared to the 2.93 $cmol_+/kg$ of the PL Type, probably due to the larger clay range in the IDD Type. The Fe content is lower in the IDD Type ($\bar{x}$ = 163 $mg.kg^{-1}$) than in the Moist Grasslands ($\bar{x}$ = 403 $mg.kg^{-1}$). Resistance is very high in the IDD Type ($\bar{x}$ = 11 426Ω, compared to 9 193 Ω in the Moist Grasslands).

5.5 Conclusion

The five different wetland types on the MCP and their respective zones can be described in terms of the presence of three major substrate types: organic, clay, and sand. The occurrence of specific soil forms are therefore mostly correlated to these substrates types. A little clay has a lot of influence on the MCP. Although very few soil samples analysed in this study classified as pure clay and mostly fell in the sandy loam textural class, the presence of even small amounts of clay has a major distinguishing factor in the morphological, physical and chemical properties of different wetland types and zones. The accentuated effect that the little clay has on differences between wetland types allows soil forms to be strongly associated with certain wetland types. This is substantiated by Morgenthal et al. (2006) who also classified two vegetation types based on either sandy- or clay dominated substrates.

According to Faulkner & Richardson (1989) and Reddy & DeLaune (2008), a high degree of variability exists among wetland types and even within wetland types, especially in terms of soil physicochemical properties. Carbon was found to be unusually high in Zone 1 of the Moist Grasslands. High carbon contents also occur in the two middle zones of the Muzi Swamp and Interdunal Depressions, which are considered peatlands. The PP, and DP Types, as well as the outer two zones of the Muzi Swamp are clay-enriched and calcic. The pH was therefore also high in these types. The Moist Grasslands and the outer two zones of the Interdunal Depressions are dominated by apedal, aeolian, sandy soils. The combination of clay, carbon, and pH is the major soil properties responsible for variation of the CEC and basic cations. The dataset of this study would be very valuable for further investigation into the exact relationship between these properties on the MCP, because the different wetland types and zones have different ranges and combinations of clay, carbon, and pH. Fe was found to be very high in the Muzi Swamp and the Moist Grasslands. Resistance was very high in the Moist Grasslands and Interdunal Depressions.

Chapter 6
COMPARISON OF WETLAND TYPES AND –ZONES DOWN A TOPOGRAPHICAL GRADIENT

6.1 Introduction

There is debate within South Africa's wetland community regarding the delineation, naming, and characteristics of the various wetland zones, and how and where to draw the boundaries. The unique environment of the Maputaland Coastal Plain (MCP) adds to these questions by deviating from what is currently accepted as wetland delineation guidelines (DWAF 2005).

While Chapter 5 deals with the general characteristics of the various wetland types and their respective zones on the topographical gradient, this chapter will discuss the similarity and dissimilarity of the wetland types and these zones. This chapter consists of two parts. Firstly, the comparison of wetland sites will be investigated in terms of the distribution and variation of each type's chemical and physical characteristics. The second part of the chapter deals with the significant differences between certain chemical properties of the various zones within each wetland type.

The aim of this chapter is two-fold. Firstly it compares all the wetland sites to establish whether there are significant differences between the main wetland types as discrete units. Secondly, the change of the various soil variables on the different positions on the topographical gradient (zones) will be compared, to determine whether a sharp change of any of these properties can significantly indicate wetland zone boundaries, and which of these zones are similar.

6.2 Comparison of all study sites in terms of soil variables

A Principal Component Analysis was conducted to investigate the relationship between wetland types and -zones, and determine the main influencing environmental variables on these relationships. An inspection of the biplot after the first PCA iteration, revealed that some of the variables were found to be co-linear. These were eliminated by an inspection of the biplots and variable loadings of each variable after each of three iterations. N, Ca, K, and Na were removed based on a correlation coefficient of $r^2 > 0.85$.

The first two axes of the PCA accounted for 78.46% of the cumulative variance (Figure 6.1). An eigenvalue of 4.62 (57.77% of variance) and 1.66 (20.69% of the variance) were obtained for the Axes 1 and 2 respectively. The five wetland types are clustered separately into four distinct groups. The Tembe Park- and Utilised Perched Pans are grouped together (Group 3), and the sandy terrestrial sites of the Interdunal Depressions cluster with the Moist Grasslands (Group 4). Group 1 represents the sites with high organic substrates of the Interdunal Depressions (Zones 1 and 2), Group 2 the Muzi Swamp, Group 3 the Perched Pans, and Group 4 the Moist Grasslands. Each of these groups is associated with different indicative soil properties. Group 1 is characterised by high organic carbon substrates; Group 2 is dominated by the cations (Ca, Na, and K removed from the analysis due to co-linearity with Mg, CEC, and resistance), Fe, and Mn; Group 3 by clay and pH; and Group 4 by high resistance.

Within these groups secondary gradients are also apparent. Zones 1 and 2 of the Muzi Swamp (Group 2) are located close to Group 1 due to the similarity in high organic substrate, while the more upland sites (Zones 3 and 4) are similar to Group 3 with its high clay content and pH values due to the buffering influence of the calcium carbonate in these sites (refer to Chapter 5). The two Zone 1 sites from the Moist Grasslands are included in Group 1 due to their high organic substrate. Even within Group 4 there is a clear gradient from the Zones 2 of the Moist Grasslands close to Axis 2 (being more similar to Group 1), to Zone 4 of both the Moist Grasslands and Interdunal Depressions, which are located on the farthest left side of Axis 1.

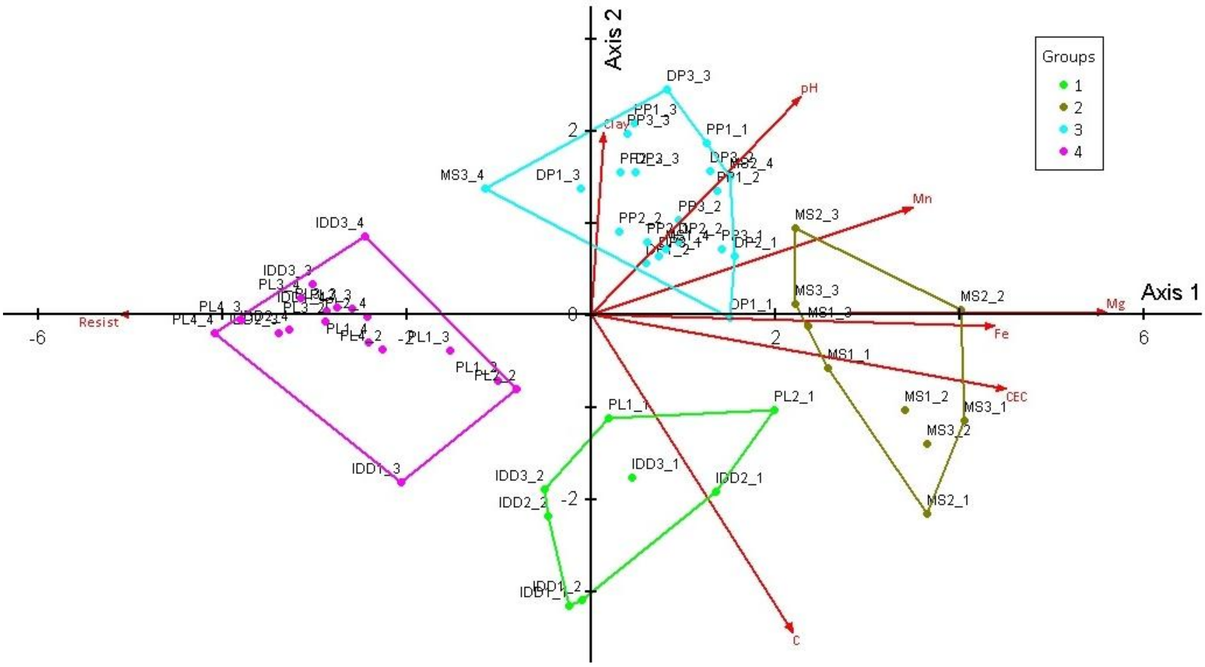

Figure 6.1. The PCA results for the various wetland sites.

6.3 Comparison of wetland zones in terms of soil variables

The results from Model 3 are presented, as this model does not assume that the effect of depth is linear, and does not assume that the zone*depth interaction is not significant. The results from this model are therefore valid for all dependent variables and soil types. The zone*depth interaction term, however, is statistically significant in only a few cases (Table 6.1):

Table 6.1. P-values for the zone*depth interaction term in Model 3, per wetland type. Significant interactions (i.e. where the change with depth between all zones is inconsistent) are shaded in grey.

Variable	Wetland Type

	DP	IDD	MS	PL	PP
Carbon	0.3922	0.2639	0.0025	0.5303	0.4325
Calcium	0.9594	0.8930	0.0114	0.6521	0.0461
CEC	0.4398	0.8468	0.0657	0.6273	0.0424
Fe	0.4013	0.1536	0.9660	0.0005	0.0007
K	0.5228	0.0586	0.8160	0.1546	<.0001
Mg	0.3413	0.8828	0.2441	0.5690	0.0004
Mn	0.9790	0.3892	0.3810	0.1603	0.0011
Na	0.0015	0.2435	0.0245	0.1240	0.0056
N	0.9589	0.9131	<.0001	0.1963	0.4987
pH	0.4447	0.8551	0.0044	0.9437	0.2257
Resistance	0.4664	0.2157	0.0023	0.9360	<.0001

When the zone*depth interaction is not insignificant, differences between zones are (approximately) constant with depth. In this case, assumptions about the differences between zones will therefore be valid for the whole of the 400 mm sample depth. However, Model 3 fits the zone*depth interaction term, and therefore accommodates also those cases where the zone*depth interaction is significant and therefore differences between zones are not constant with depth. Since there proved to be too many interactions of wetland type with zone, depth, and transect, the results of the various wetland types are discussed separately in the following sections.

The zone means from Model 3 are presented in Table 6.2. The pairwise differences between zones from Model 3 are presented for the various wetland types in sections 6.3.1 - 6.3.5. In these tables only the zones between which significant differences were found are presented. Cases where significant differences existed between zones not adjacent to each other (e.g. zones 1 and 3) were also omitted. Only a selection of the figures of variables is included below. For the full set of figures for all variables, refer to Addendum C.

Table 6.2. Zone means (logarithmic scale) from mixed model analysis (Model 3).

Type	Zones	Variables										
		C	**Ca**	**CEC**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**N**	**pH**	**Resistance**
DP	1	0.49	1.94	3.11	7.69	0.46	1.71	2.78	1.27	7.20	6.58	5.93
	2	-0.05	1.97	2.73	7.53	-0.04	1.44	2.84	0.69	6.54	7.07	6.32
	3	-0.80	1.10	2.06	6.98	-0.95	0.59	3.47	0.53	6.03	8.11	6.10
IDD	1	2.56	1.43	3.36	7.22	-2.77	0.72	1.65	0.10	8.69	4.81	6.70
	2	2.15	0.64	3.16	6.09	-2.84	0.23	0.94	-0.33	8.32	4.57	7.29
	3	-0.09	-0.30	1.24	4.67	-3.04	-1.11	1.26	-2.10	6.32	5.02	8.75
	4	-0.70	0.03	0.74	5.31	-2.99	-0.95	1.74	-2.47	5.75	5.52	9.12
MS	1	2.63	4.23	3.94	8.76	-0.03	2.49	4.57	2.55	8.91	7.25	4.54
	2	2.63	4.27	4.30	9.09	-0.20	2.37	4.93	2.28	8.93	7.76	4.87
	3	1.15	3.64	3.01	8.23	-0.24	2.22	4.19	0.02	7.45	8.72	6.58
	4	-0.71	2.55	2.18	6.92	-1.52	1.12	4.07	-1.57	6.16	8.51	7.77
PL	1	1.40	0.63	2.58	7.73	-2.01	0.36	2.24	0.57	7.39	4.96	5.61
	2	0.15	0.11	1.65	6.29	-2.81	-0.44	0.84	-1.19	6.47	5.27	8.02
	3	-0.38	0.45	1.24	5.41	-2.88	-0.80	1.05	-2.10	6.08	5.30	9.00
	4	-0.54	0.06	1.39	5.10	-3.62	-1.16	1.16	-1.97	5.63	5.20	9.27
PP	1	-0.11	1.72	2.42	7.50	-0.15	1.53	4.20	1.32	6.46	6.69	5.76
	2	-0.34	0.71	2.46	7.22	-0.59	1.14	4.10	1.57	6.45	6.88	6.03
	3	-1.03	0.85	2.08	6.80	-1.27	0.83	4.23	1.45	5.87	7.67	6.27

6.3.1 The Muzi Swamp (MS Type)

Table 6.3. The significant pair-wise differences between zones within the Muzi Swamp. The differences between zones 1 and 2 are shaded in light grey, while zones 2 and 3 are shaded in dark grey.

The MS Type					
	Zones		Pair-wise differences	t-value	Pr > |t|
C	2	3	1.472	3.11	0.021
	3	4	1.868	3.95	0.008
N	2	3	1.476	3.15	<0.020
	3	4	1.293	2.76	<0.033
Fe	3	4	1.31	3.08	<0.015
Mn	2	3	0.736	2.87	<0.029
K	3	4	1.282	2.9	<0.027
Mg	3	4	1.096	2.36	<0.046
Ca	3	4	1.094	2.88	<0.028
Na	2	3	2.262	6.34	<0.001
	3	4	1.586	4.44	<0.004
Resist	2	3	-1.714	-4.47	<0.002
	3	4	-1.191	-3.11	<0.015

Within the Muzi Swamp significant differences occur between zones 2 and 3 as well as between zones 3 and 4. Except for Na, the cations notably do not have differences between zones 2 and 3. Most profiles (Figure 6.2 to Figure 6.4) illustrate the similarity of zones 1 and 2. Carbon (Figure 6.2) and N again have corresponding profiles. Fe and resistance have profiles similar to those of C and N. Manganese (Figure 6.3) has a very different pattern of similarity - zones 1 and 2, and zones 3 and 4, are similar in the topsoil, but become more discernible with depth. The values for zone 2 are much higher than for zone 1, resulting in the significant difference between zones 2 and 3. Despite this, Mn does not appear to be a good, constant indicator of zoning. Magnesium and Ca have similar profiles to K (Figure 6.4), with zone 2 overlapping with both zones 1 and 2 with regards to Mg and K.

The Muzi Swamp has many variables where the zone*depth interaction is not significant (Figure 6.1), namely the cations (except for Na), CEC, Fe and Mn. Since it signifies that these variables do not decrease with depth constantly between zones, it should be concluded that none of these variables are suitable for use when investigating zonation.

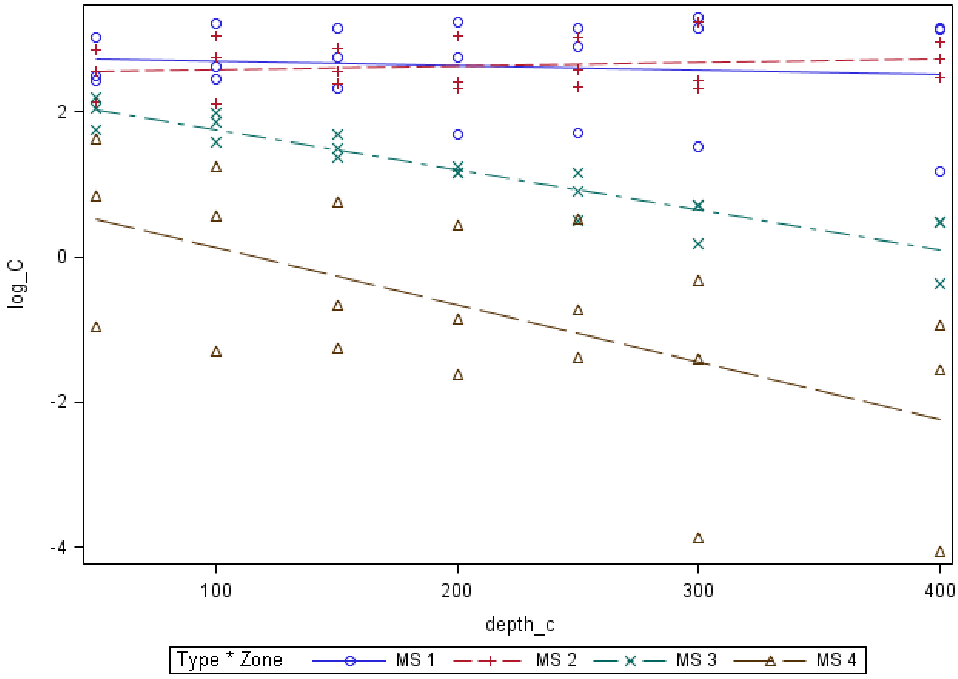

Figure 6.2. Carbon variation with depth in the Muzi Swamp (log scale).

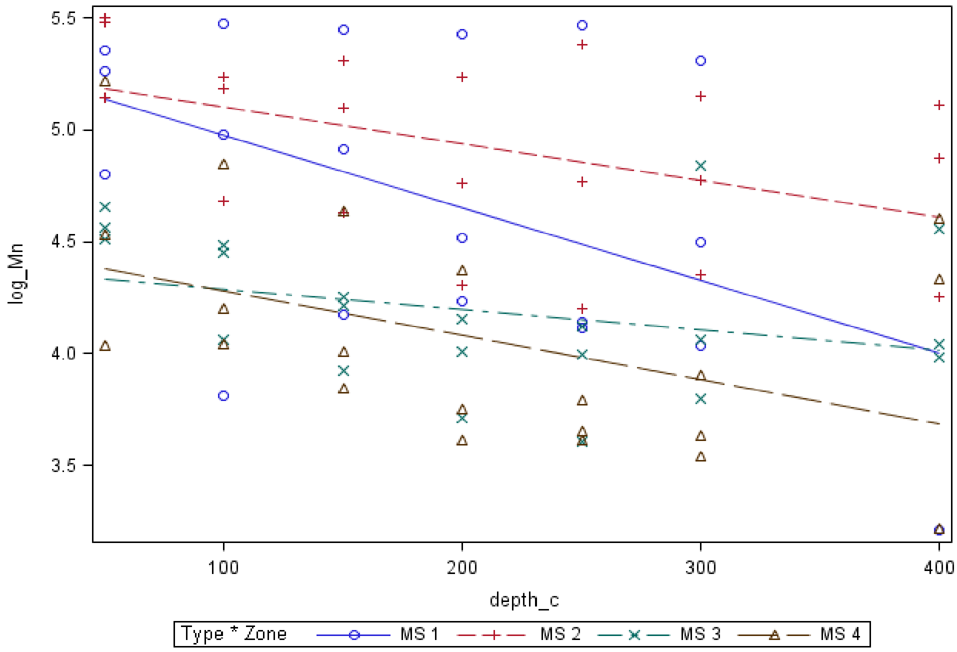

Figure 6.3. Mn variation with depth in the Muzi Swamp (log scale).

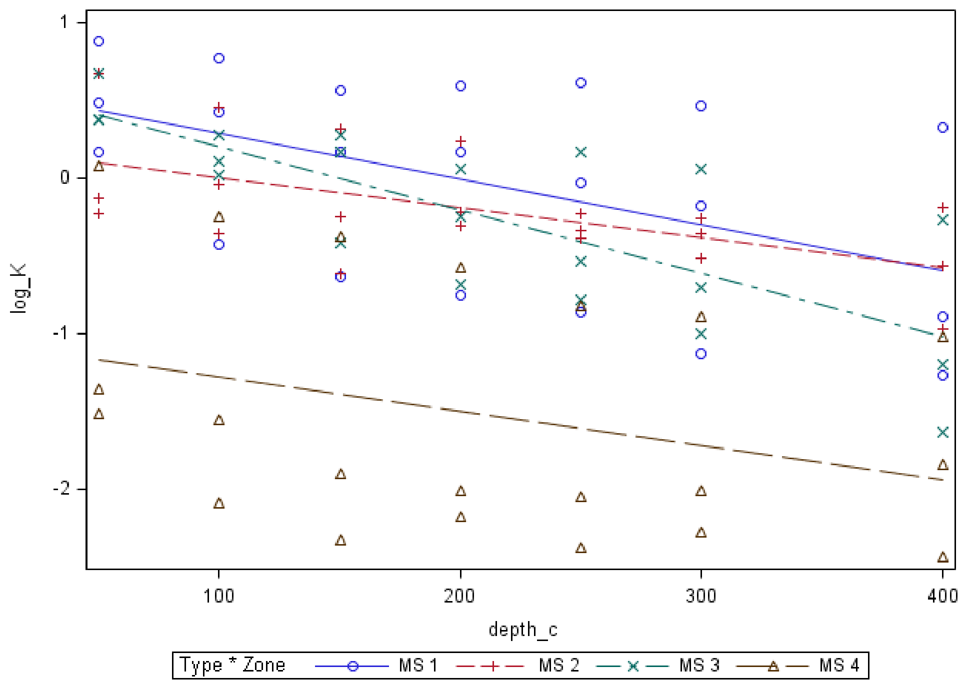

Figure 6.4. K variation with depth in the Muzi Swamp (log scale).

6.3.2 The Tembe Park Perched Pans (PP Type)

Table 6.4. The significant pair-wise differences between zones within the PP type. The differences between zones 1 and 2 are shaded in light grey, while zones 2 and 3 are shaded in dark grey.

The PP Type					
	Zones		**Pair-wise differences**	**t-value**	**Pr > |t|**
C	2	3	0.686	3.07	0.037
Ca	1	2	1.014	2.57	0.043

The Tembe Park Perched Pans have very few variables changing constantly over depth and with significant differences between zones (Table 6.1 and Table 6.4). This wetland type has only three zone*depth interactions that are not significant, namely C, N, and pH (Table 6.1). From these variables only C has significant differences (between zones 2 and 3). Figure 6.5 indicates how zones 1 and 2 overlap. Ca has differences between zones 1 and 2, but does not decrease with depth constantly between zones, and should therefore not be regarded suitable for determining zonation.

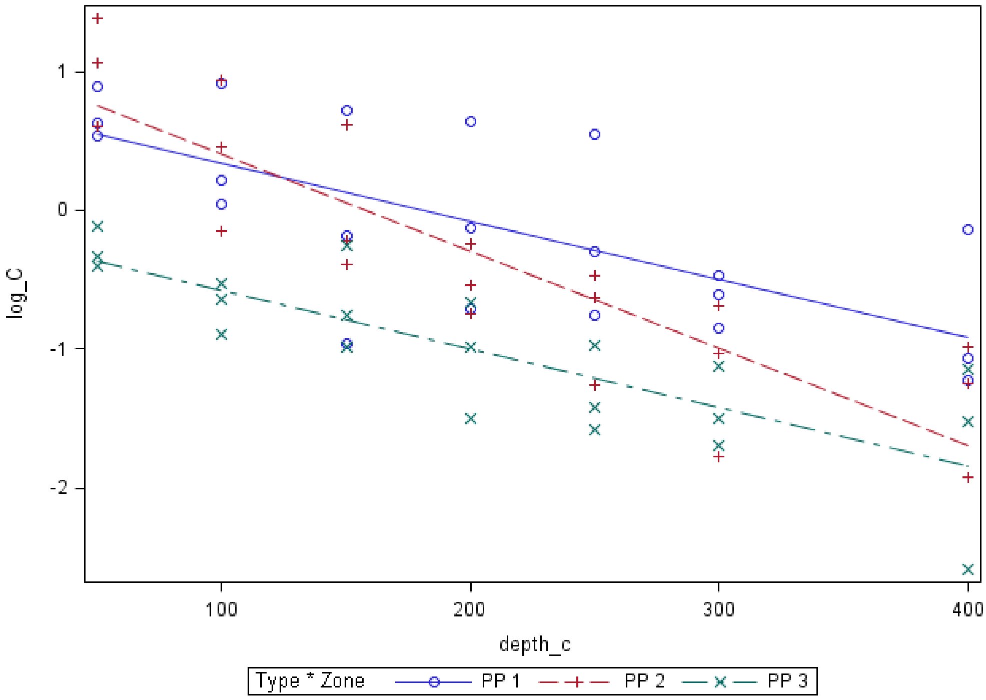

Figure 6.5. C variation with depth in the Tembe Park Perched Pans (log scale).

6.3.3 The Utilised Perched Pans (DP Type)

Table 6.5. The significant pair-wise differences between zones within the DP type. The differences between zones 1 and 2 are shaded in light grey, while zones 2 and 3 are shaded in dark grey.

The DP Type					
	Zones		**Pair-wise differences**	**t-value**	**Pr > |t|**
C	1	2	0.542	6.61	<.0001
	2	3	0.756	9.23	<.0001
N	1	2	0.664	6.51	<0.001
	2	3	0.505	4.95	<0.003
CEC	2	3	0.670	3.28	<0.01
Mg	2	3	0.85	2.92	<0.017
pH	1	2	-0.489	-2.99	<0.004
	2	3	-1.04	-6.35	<.0001

Where there are differences present between zones they are strongly significant (Table 6.5). Although there are significant differences between zones 1 and 2 for C, N and pH, the differences between zones 2 and 3 are always more prominent.

Carbon in all zones decreases constantly with depth (Table 6.1 and Figure 6.6). Nitrogen decreases in a very similar pattern to carbon (Addendum C). CEC and Mg show a similar pattern to each other, and in both cases the zone 1 increases with depth while zones 2 and 3 decreases with depth. There is a significant difference only between zones 2 and 3 (Figure 6.7). A lot of outliers are present (also in pH), which result in these three variables probably not being the best indicators of zoning.

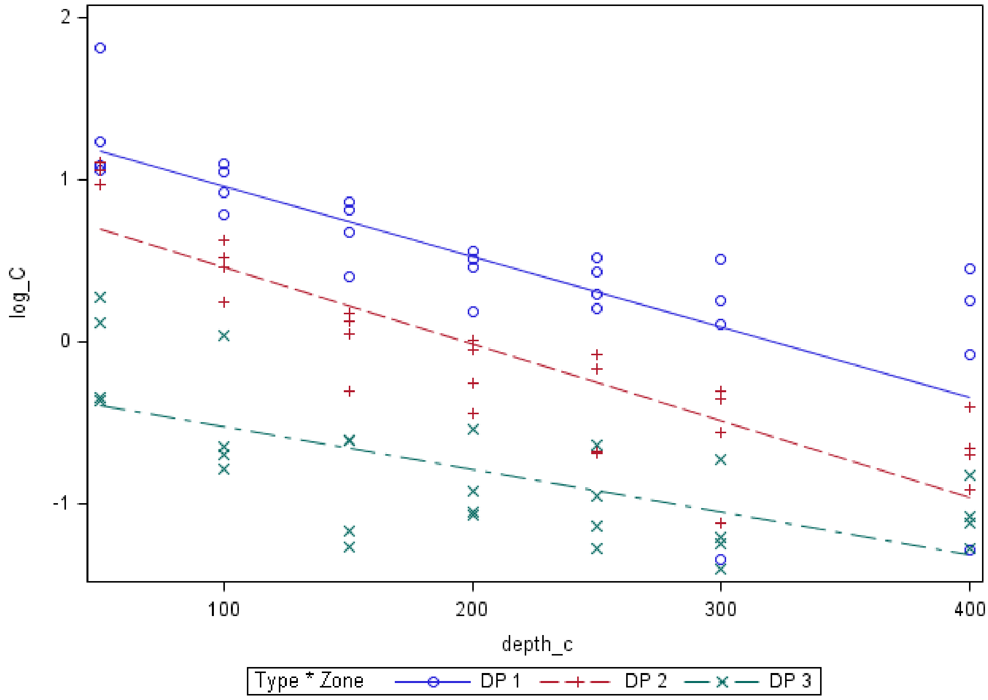

Figure 6.6. Carbon variation with depth in the Utilised Perched Pans (log scale).

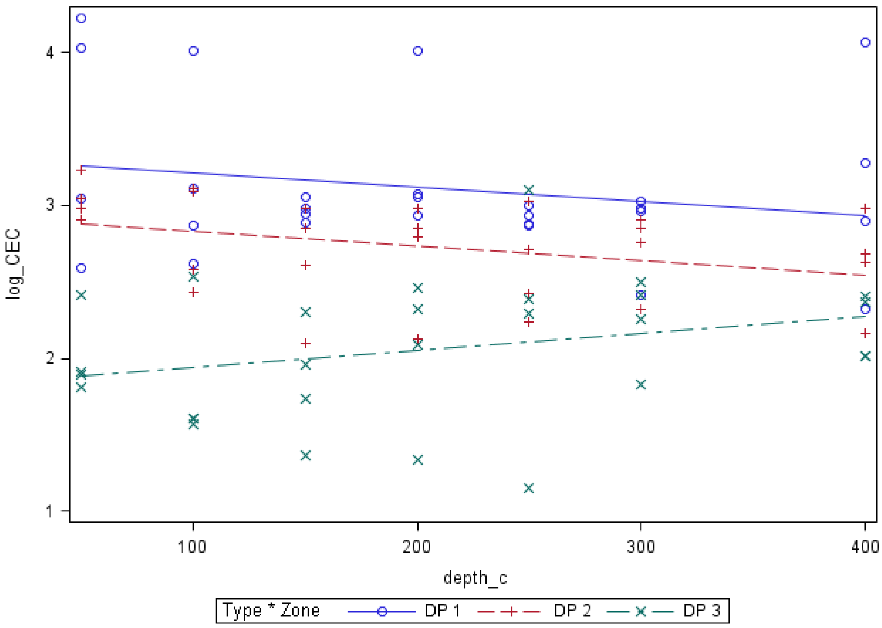

Figure 6.7. CEC variation with depth in the Utilised Perched Pans (log scale).

6.3.4 Moist Grasslands (PL Type)

Table 6.6. The significant pair-wise differences between zones within the PL type. The differences between zones 1 and 2 are shaded in light grey, while zones 2 and 3 are shaded in dark grey.

The PL Type					
	Zones		Pair-wise differences	t-value	Pr > |t|
C	1	2	1.248	3.42	0.010
N	1	2	0.920	2.65	<0.03
CEC	1	2	0.927	2.26	0.048
Fe	1	2	1.44	3.42	<0.011
	2	3	0.88	2.71	<0.030
Mn	1	2	1.401	3.84	<0.006
K	3	4	0.738	2.39	<0.046
Na	1	2	1.756	2.85	<0.023
Resist	1	2	-2.407	-4.94	<0.001
	2	3	-0.979	-2.66	<0.034

In contrast to all the other wetland types, the Moist Grasslands have significant differences, mostly between zones 1 and 2 (Table 6.6). Most variables exhibit similar patterns over depth, with zone 1 significantly different from the rest of the zones. Zones 2, 3, and 4 become more similar with depth, and often overlap at some point. Carbon (Figure 6.9), N, and CEC display similar changes over depth. Fe exhibits differences between zones 2 and 3 as well, but is also indicated to not change constantly over depth (Table 6.1). Potassium (Figure 6.8) is the only variable with differences between zones 3 and 4. Zone 1 of the variable resistance (Figure 6.10) is significantly removed from the rest of the zones. Zone 2 also appears to be quite separate, but there is high variability in this zone.

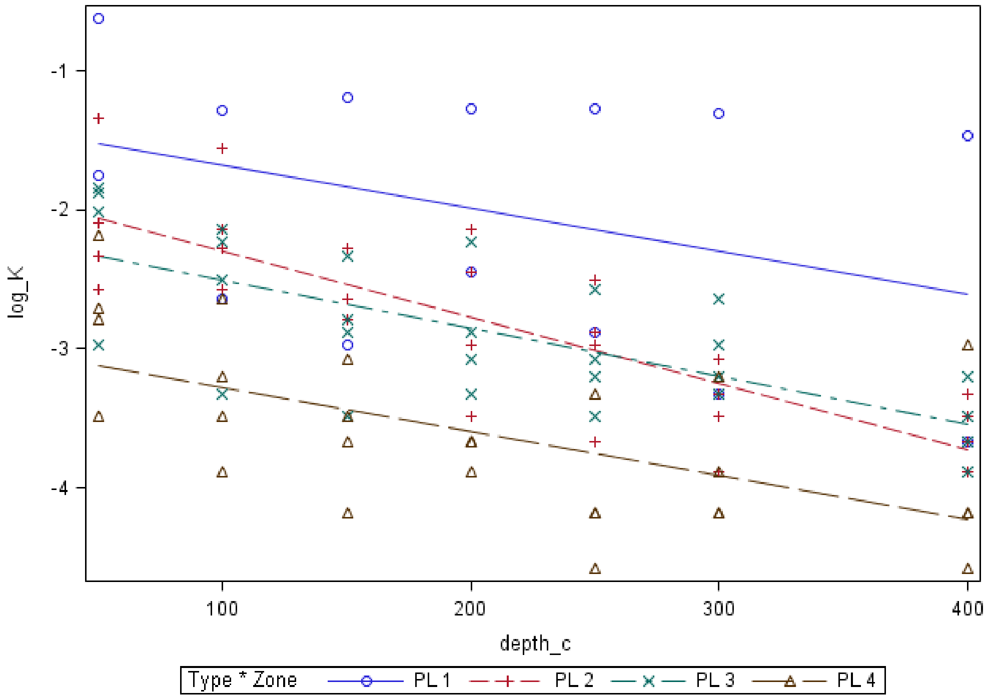

Figure 6.8. K variation with depth in the Moist Grasslands (log scale).

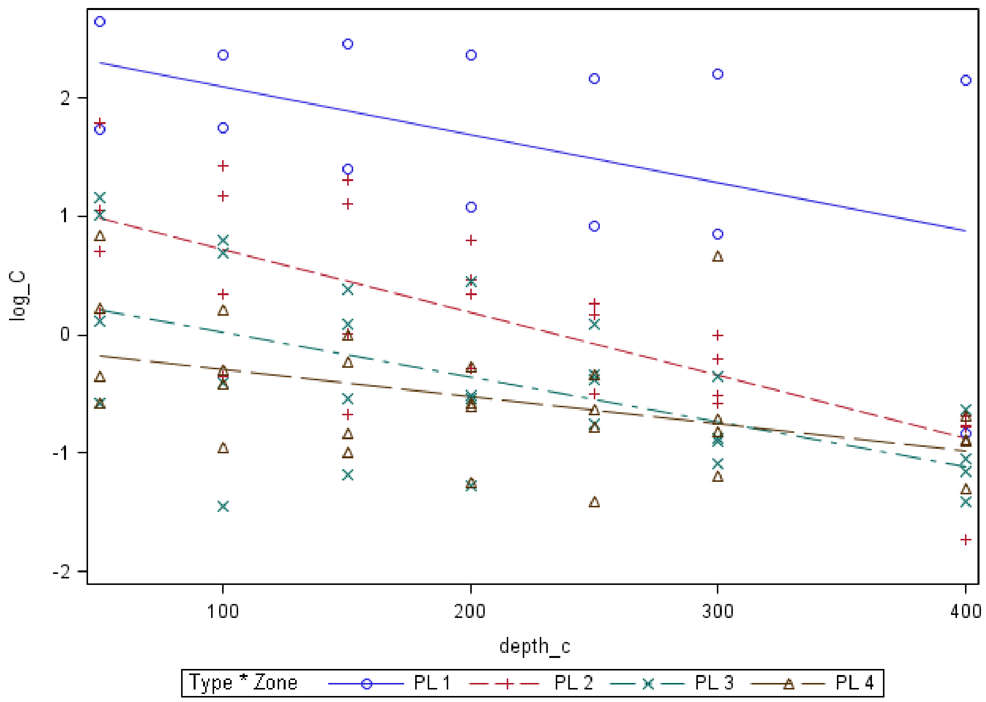

Figure 6.9. C with depth in the Moist Grasslands (log scale).

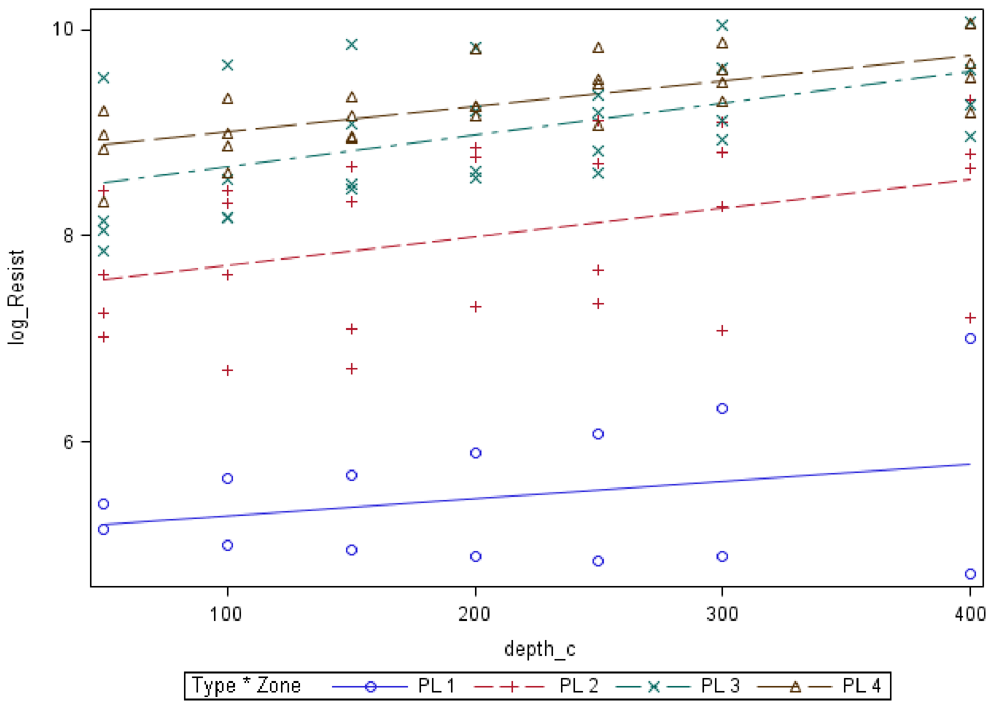

Figure 6.10. Resistance with depth in the Moist Grasslands (log scale).

6.3.5 Interdunal Depressions (IDD Type)

Table 6.7. The significant pair-wise differences between zones within the IDD type (log scale). The differences between zones 1 and 2 are shaded in light grey, while zones 2 and 3 are shaded in dark grey.

The IDD Type					
	Zones		Pair-wise differences	t-value	Pr > |t|
C	2	3	2.236	7.46	0.0003
N	2	3	2.001	5.96	<0.001
CEC	2	3	1.923	5.53	<0.001
Fe	1	2	1.125	3.54	<0.012
	2	3	1.426	4.46	<0.004
Mg	2	3	1.347	3.48	<0.008
Na	2	3	1.77	3.42	<0.009
Resist	2	3	-1.463	-2.47	<0.039

Within the Interdunal Depressions, the zone*depth interaction is not statistically significant for the dependent variables (Table 6.1); implying that differences between zones are constant with depth for all variables. The Interdunal Depressions are the only wetland type where this is the case for all variables. The most significant difference within the Interdunal Depressions is found between zones 2 and 3. Despite the Interdunal Depressions having four zones (unlike the Utilised- and Tembe Park

Perched Pans), differences between zones 3 and 4 are notably absent. Fe is the only variable where significant differences are also found between zones 1 and 2 (Table 6.7).

Figure 6.11 to Figure 6.13 illustrate the large differences between zones 2 and 3 for all variables. Once again C and N present similar graphs, where the two parameters decrease with depth in a constant manner. CEC and Na behave similarly with depth in the Interdunal Depressions, with zones 1 and 2 being almost similar in the top 150 mm. In both the cases of the Mg and Fe variables, zones 3 and 4 are switched around, which emphasize the similarity of the bottom two zones.

Pretorius et al. (2014) attribute the drastic difference between zones 2 and 3 to the slope of the dune between which the Interdunal Depressions occur. The transition between the two high organic zones at the bottom of the dune and the two non-organic zones on the slope of the catena is very sharp, and therefore, in terms of all variables, merit the combination of zones 1 and 2, and of zones 3 and 4 respectively.

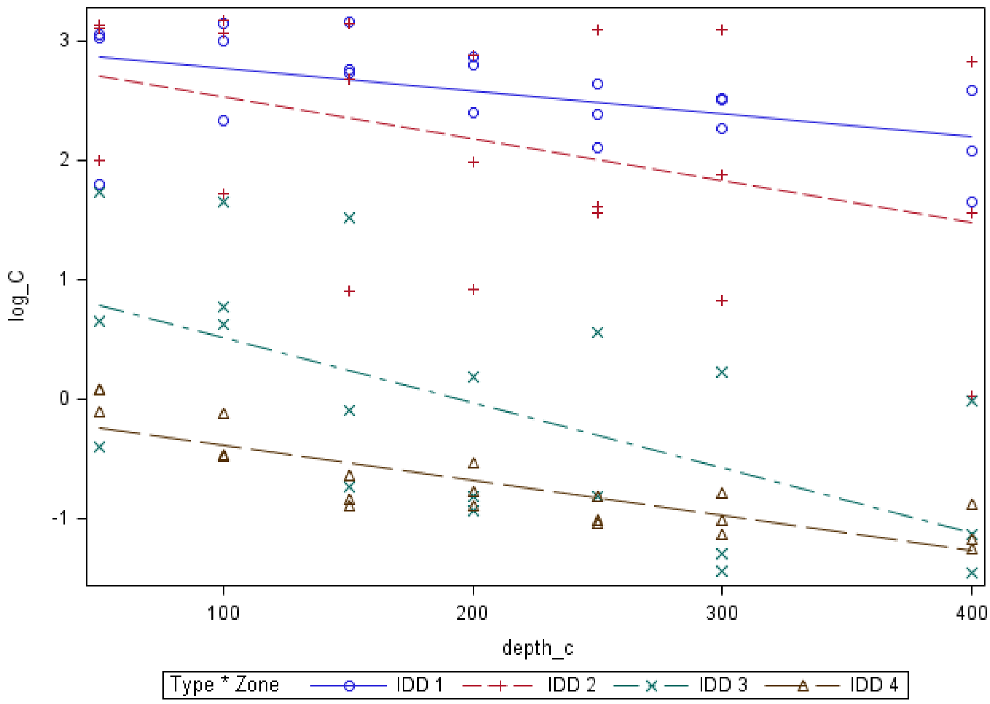

Figure 6.11. C variation with depth in the IDD type (log scale).

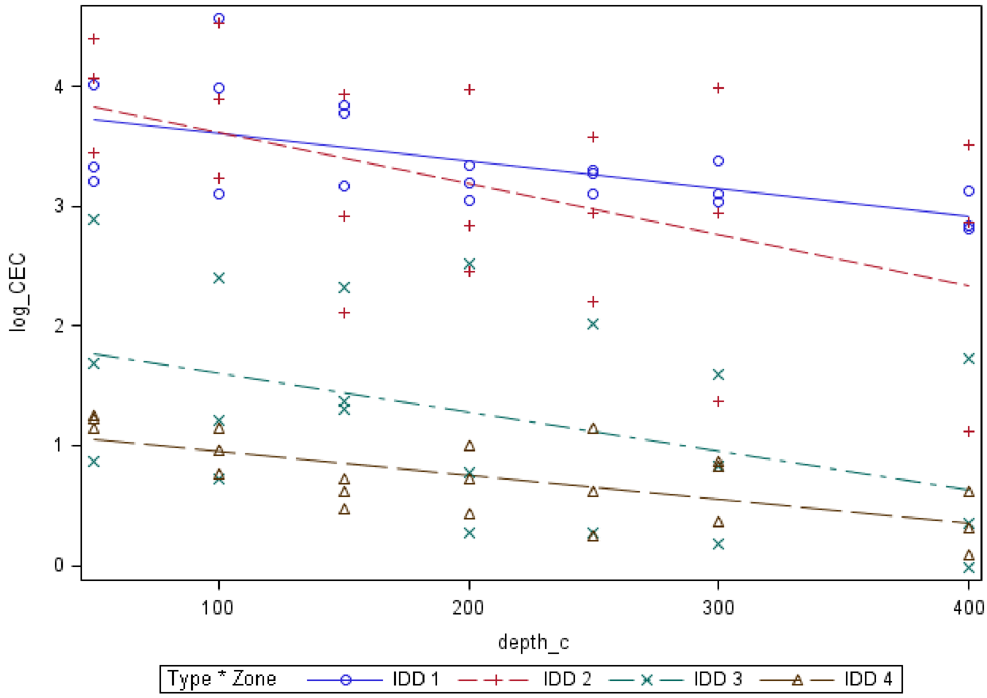

Figure 6.12. CEC variation with depth in the IDD type (log scale).

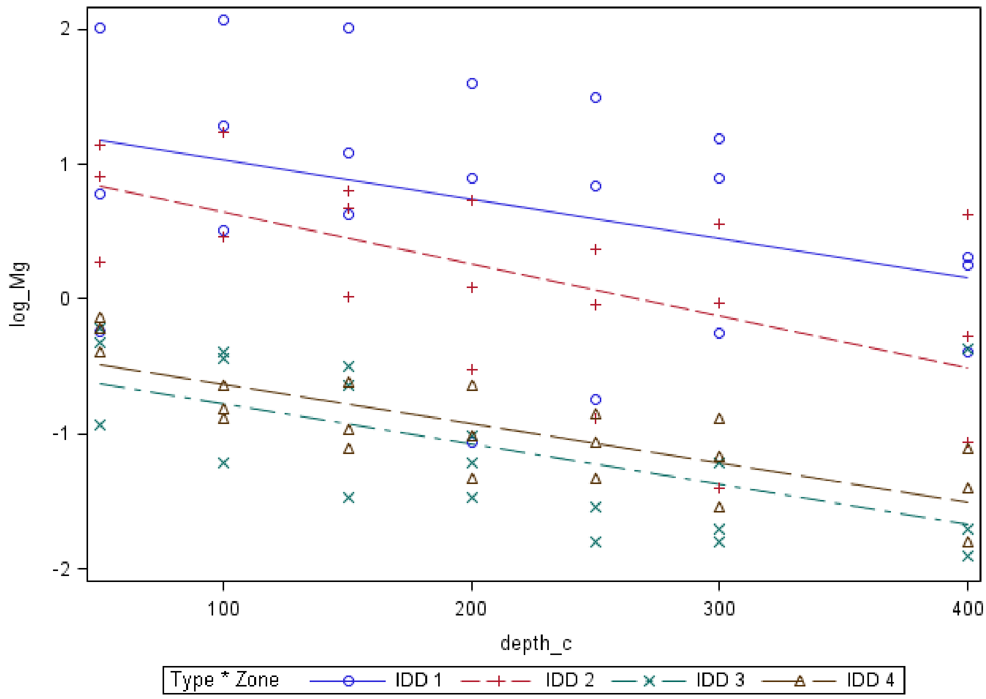

Figure 6.13. Mg variation with depth in the IDD type (log scale).

6.4 Discussion

The PCA ordination of the soil variables indicates that generally wetland types have a distinct character in terms of carbon, clay, pH, manganese, magnesium, iron, CEC, and resistance, which differentiates the types from each other. An illustration hereof is the dissimilarity of the permanently wet sites of the Muzi Swamp and Interdunal Depressions, even though both are characterised by high organic carbon content, due to the richness in cations of the Muzi Swamp. However, sites in certain topographical positions may sometimes be similar across certain wetland types due to similar substrates, as is the case with the sandy upland Interdunal Depressions sites, which cluster together with the sandy upland Moist Grassland sites within the Moist Grassland-dominated Group 4.

Most soil variables exhibit a distinct pattern of either accumulation or depletion down a topographical slope. Should each transect in this study be investigated individually it would be clear that with every change on the topographical gradient (whether it be slope, vegetation, or wetness) certain soil properties will also significantly change. However, since the change in properties is not always constant between the different transects (or repetitions) in each wetland type, deriving assumptions about the ability of soil properties to indicate (with a fair amount of confidence) the different zones in wetlands is made difficult.

The series of mixed models used in this chapter address this problem, and elucidate the variation of each soil property that can be expected in the zones of every wetland type, despite variation. The Muzi Swamp had the most soil variables where significant differences were found between the zones (9 out of the 11 variables), while the Tembe Park Perched Pans had the least (2 out of the 11 variables). Therefore there are more differences down the topographical gradient in the Muzi Swamp than in the Tembe Park Perched Pans. Carbon is the only variable which constantly exhibits significant differences between zones in all wetland types. Nitrogen also indicates significant differences between zones in a fairly constant manner, and often displays a similar pattern of variation with depth as carbon. pH is the worst indicator of differences between zones. Manganese and potassium demonstrate differences only in the Muzi Swamp and Moist Grasslands; and Calcium only in the Muzi Swamp and Tembe Park Perched Pans.

6.5 Conclusion

The variability of eleven soil properties (variables) was examined to determine whether there are differences between the wetland types, and where the significant differences between the wetland zones of each wetland type are situated.

Wetland types may share characteristics based on similar soil properties, but in general wetland type clusters are distinctly different from each other. Two main gradients are visible from Figure 6.1: firstly there is a wetness gradient from Group 1 (high organic substrates) to Groups 3 and 4 (more seasonal sites), to Group 4 (leached, upland sites); and secondly there is a productivity gradient where Groups 1, 2, and 3 are characterised by high organic and basic substrates, to Group 4, which is low in cations, iron, and manganese.

The zones between which statistically significant differences can be found vary for each wetland type. Similarly, different soil properties indicate different zoning. The most likely scenario to indicate wetland versus non-wetland conditions are emphasised in italics.

<u>The Muzi Swamp displays two scenarios -</u>

1. Zones 1 and 2 can be combined and are statistically different from Zones 3 and 4 (C, Na, N, resistance).
2. *Zones 1, 2, and 3 can be combined, and is statistically different from Zone 4 (Ca, Fe, K, Mg).*

<u>The Tembe Park Perched Pans display two scenarios -</u>

1. *Zones 1 and 2 can be combined and are statistically different from Zone 3 (C).*
2. There are no significant differences between any of the zones (therefore no zonation) (CEC, Mg, Mn, Na, N, pH, resistance).

<u>The Utilised Perched Pans display three scenarios -</u>

1. The zones are all unique in their own right (C, N, and pH).
2. *Zones 1 and 2 can be combined, and would be significantly different from Zone 3 (CEC and Mg).*
3. There are no significant differences between any of the zones (therefore no zonation) (Ca, Fe, Mn, Na, and resistance).

<u>The Moist Grasslands display three scenarios -</u>

1. Zone 1 is statistically different from Zones 2, 3, and 4; and as there was no statistical difference between the latter three zones, they can be combined (C, N, CEC, Mn, and Na).
2. *Zones 1 and 2 are statistically different from Zones 3 and 4, and as there was no statistical difference between the latter two zones, they can be combined (Fe, resistance).*
3. There are no significant differences between any of the zones (no zonation) in terms of Ca, and pH.

<u>The Interdunal Depressions display three scenarios -</u>

1. Zones 1 and 2; and Zones 3 and 4 can be combined. These two groups are statistically different from each other (C, CEC, Mg, Na, N, and resistance).
2. *Zones 1, 2, and 3 can be combined, and are significantly different from Zone 4 (Fe).*
3. There are no significant differences between any of the zones (no zonation) (K and Mn).

The soil elements accumulate and deplete down the topographical gradient in different manners, and therefore the outcomes of a zone delineation exercise will be different every time another variable is used to look at differences between zones. From all the tested variables carbon is the most reliable, as it is one of the few variables which decreases constantly with depth, and consistently exhibits significant differences between zones in all of the five wetland types. However, in this study carbon probably is not a good indicator of wetland boundaries. Especially in the peatlands (Muzi Swamp and Interdunal Depressions) and even the Moist Grasslands, the carbon will indicate the edge of the high organic zones to be the boundary, while in fact the true boundary can stretch beyond that in the seasonally flooded soil.

Chemical soil properties (even carbon, which is thought to be an indicator of wetland conditions) are therefore not a good indicator of wetland boundaries on the MCP, as they are extremely variable and also will be different in different wetland types. Although certain patterns can be discerned and probably applied to determine wetland conditions, it is not a rapid field method.

Chapter 7
VEGETATION AS AN INDICATOR OF WETLAND CONDITIONS ON THE MCP

7.1 Introduction

This chapter aims to elucidate wetland zones by investigating vegetation composition, influencing environmental properties, the indicator value of certain key species, and the fidelity of 'wet' species to wetlands.

The specific aims of this chapter are:

- To establish the relationship between vegetation and certain soil properties in the various wetland types and -zones.
- To determine which species are indicative of wetland conditions on the MCP.
- To determine the prevalence of vegetation relevés to wetland conditions.

7.2 Results

7.2.1 The relationship between vegetation and soil properties

The vegetation data is used to apply a direct ordination in order to understand the relationship between the vegetation composition and certain soil properties, as well as to see how the combination of vegetation and soil gives an indication of the various wetland types and –zones. This will be supported by an Indicator Species Analyses in order to establish the main species giving indications of wetland conditions.

A species area curve was computed using the Chi^2 distance measure, and the jackknife estimates obtained. This, as well as the amount of empty cells, indicated that the number of rare species had a large influence in the data set (Peck 2010). The rare species were therefore removed, which subsequently improved the above mentioned estimates (Figure 7.1). Rare species were removed based on fewer than three occurrences within the data set.

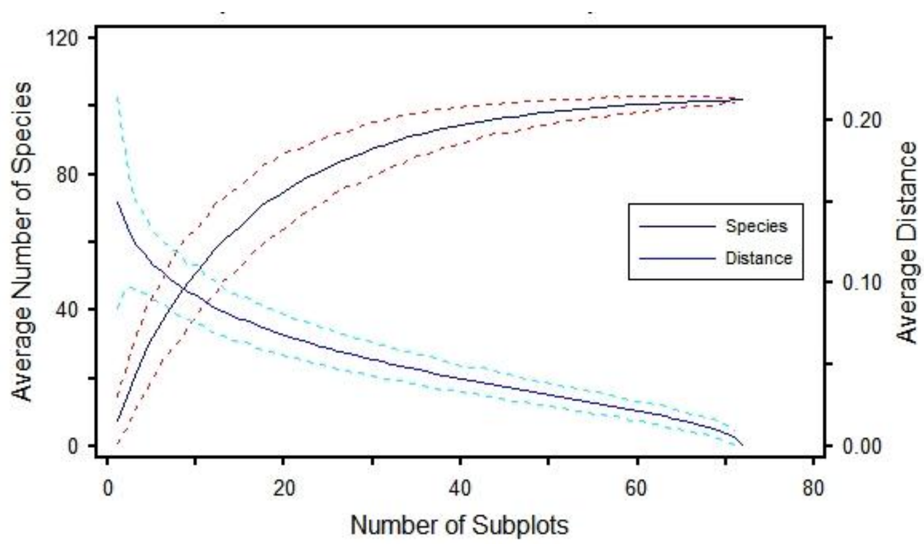

Figure 7.1. The Species are curve indicates that the amount of sampling was adequate after the removal of rare species.

The soil variables C, N, CEC, Ca, Na, Mg, K, pH, Fe, Mn, Resistance, and clay content constituted the environmental data set. Since the data were found to be slightly skewed (Kurtosis > 1 and high coefficient of variance percentage) both the environmental as well as the species data were log-transformed (McCune & Grace 2002). The species data were log-transformed using Log(x+1), and the environmental data using the form $\text{Log}(x+x_{min})-\text{Log}(x_{min})$ (Peck 2010). After transformation a Canonical Correspondence Analysis (CCA) was conducted. The 'centering and normalizing' and 'optimizing rows' options were used, and the (Linear Combination) LC scores were graphed (McCune & Grace 2002). After inspection of the biplot after the first CCA iteration, some of the variables were found to be co-linear. These were eliminated by an inspection of the biplot and variable loadings of each variable. N, CEC, and Mg were removed based on a correlation coefficient of $r^2 > 0.83$.

Based on the wetland characterisation in Chapter 5, as well as field observations and literature, the relevés were placed into 'wetness' classes. These classes should not be confused with the permanent, seasonal, and temporary categories described in the wetland delineation manual developed for South Africa (DWAF 2005). Since the wetlands in this study were not delineated as per the guideline, because the 'difficult soil', the classes in Table 7.1 were devised by expert opinion specifically for these particular wetland types on the MCP. These classes were added as categorical variables to the CCA ordination in order to see how these wetness states relate to the environmental and vegetation variables.

Table 7.1. Rationale for the wetness classes devised for overlay in the CCA.

'Wetness' class	Description	Rationale	Examples
1	Permanent saturation	Natural peatlands are by definition associated with permanent saturation (Joosten & Clarke 2002). On the MCP wetlands with high organic matter, build-up is associated with a permanent high water table (Grundling et al. 2014). All plots with an organic carbon content of more than 10% were classified into this class. The cut-off percentage of 20% for peatlands was not used as some of the plots within the peatlands (e.g. the Muzi Swamp) were less than 20% although they are clearly still part of the peatland system.	Zones 1 & 2 of the Muzi Swamp (MS Type) and the Interdunal depressions (IDD Type).
2	Seasonally flooded	All wetland plots saturated for a few months per year which have less than 10% organic carbon content. This is based on visual observation over the past 5 years, personal communication with local residents, soil form, as well as literature. The presence and abundance of mottling at each site as described in Chapter 4 were also taken into account, but due to the implication of 'problematic soil' in DWAF (2005), it was not applied strictly here.	The inner zones of the PP- and DP Types; the edge of the MS Type (Matthews et al. 2001).
3	Periodically flooded	All wetland plots saturated only during high flood events. This mostly applies to the plots located outside the wetland area on, or close to, the ridge surrounding the wetland, but with evidence of periodical saturation (based on soil form, and mottling). Again, the interpretation of the absence of mottling was not regarded in a strict manner here.	The surrounding ridges of the PP- and DP Types, most of the PL Type.
4	Upland	Plots located well outside the wetland area with no evidence of wetness.	All the wetland types have plots classified as upland.

The inertia in the species data obtained by the CCA results was 13.39. The Eigenvalues were 0.693 and 0.627 for Axis 1 and 2 respectively. The cumulative percentage explained by the variance in species data was 9.9. The Pearson Correlation for the species-environment relation was 0.956 and 0.939 for axis 1 and 2, respectively. The correlations between the environmental variables and the three axes are indicated in Table 7.2.

Table 7.2. Inter-set correlations for the environmental variables.

	Axis 1	Axis 2	Axis 3
C	0.295	0.844	0.196
Ca	0.548	0.520	-0.305
K	0.871	0.059	-0.143
Na	0.889	0.176	-0.089
pH	0.535	-0.037	-0.636
Fe	0.691	0.406	-0.087
Mn	0.642	0.034	-0.584
Resist	-0.850	-0.301	0.101
Clay	0.220	-0.519	0.262

The CCA results are overlain with two categorical variables. Figure 7.2 illustrates the results of the CCA with an overlay of the wetland types, while Figure 7.3 illustrates the overlay of the wetness categories. As was found by Pretorius (2011), the wetland types are quite distinct from each other, and certain wetland types are strongly associated with each other. While Pretorius (2011) only suggested certain environmental gradients (with the study making use of indirect ordinations), the CCA presented here now statistically supports these species-environmental correlations.

The results are very similar to that obtained from the PCA for only the soil variables in Chapter 6 (Figure 6.1). Figure 7.2 indicates that the clayey Tembe Park Perched Pans (PP Type) and the Utilised Perched Pans (DP Type) are similar to each other, with the Utilised Perched Pans having a much wider distribution. Similar to Chapter 6, both these types are strongly associated with clay content, and are significantly removed from the other types. The CCA shows little affinity between the Muzi Swamp (MS Type), clay content, and pH despite the duplex soil and clay lenses which occur on the edges of the Muzi Swamp. This is in contrast to what was found by Pretorius (2011). Still, the differentiation between the Muzi Swamp and Interdunal Depressions (IDD Type) on respective sides of the positive Axis 2 can be attributed to the Muzi Swamp being richer in cations, Fe, and Mn, while the Interdunal Depressions are more dominated by leached sandy soils in the upland sites (i.e. somewhat closer to the high resistance variable). The Interdunal Depressions can probably be regarded as a dystrophic peatland, meaning it is poor in nutrients. The Muzi Swamp, Moist Grasslands (PL Type), and Interdunal Depressions all show a strong gradient from the positive Axis 2 to the negative Axis 1 – clearly from plots dominated by carbon content and resultant high cations, Fe and Mn; to plots that are poor in these soil properties and have high resistance (Figure 6.1). This is due to the wetness gradient, indicated in Figure 7.3. The permanently flooded plots are strongly affiliated with Axis 2, and the rest of the wetness gradient with Axis 1. Although the gradient is strong, the various wetness categories do not form discrete clusters. The seasonally flooded cluster overlaps with the periodically flooded- and upland clusters, as well as with the permanently saturated cluster. Conspicuously, the periodically flooded and upland clusters are very similar, although the periodically flooded cluster has a much wider distribution. Admittedly the upland areas surrounding the wetland systems have clearly been under-sampled.

Soil organic carbon has a strong association with not only the permanently saturated wetness class, but also (to a lesser degree) with those seasonally flooded plots not dominated by a clay substrate.

Fe, and Ca are more associated with carbon, and the Na, K, Mn, and pH more with clay. Resistance is the most influential variable, and is associated solely with plots that are periodically flooded or well drained (i.e. more to the upper end of the topographical slope), and located on sandy substrates. High resistance indicates an absence of salts, which is expected in these locations.

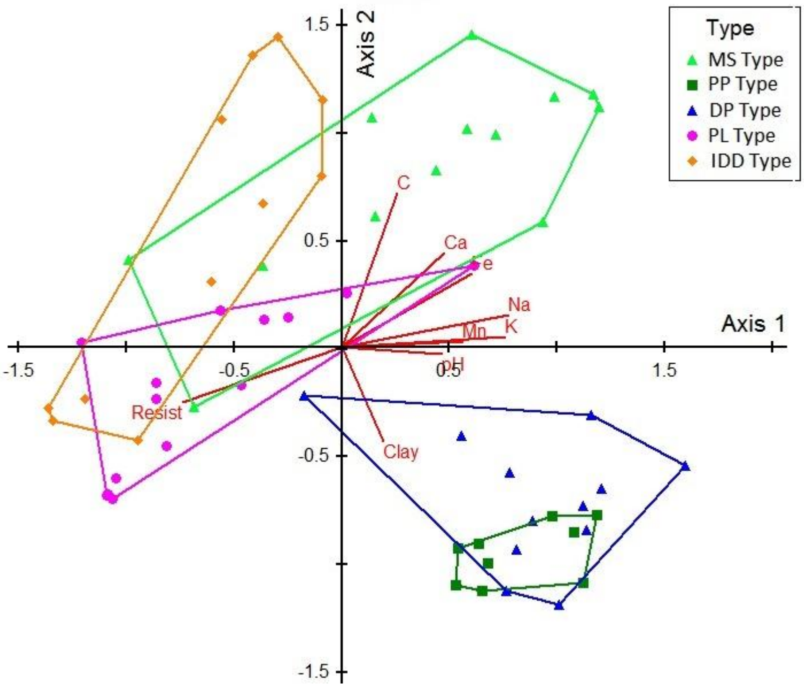

Figure 7.2. CCA results with the categorical variable wetland type as an overlay. The Eigenvalues are 0.693 and 0.627 for Axis 1 and 2 respectively.

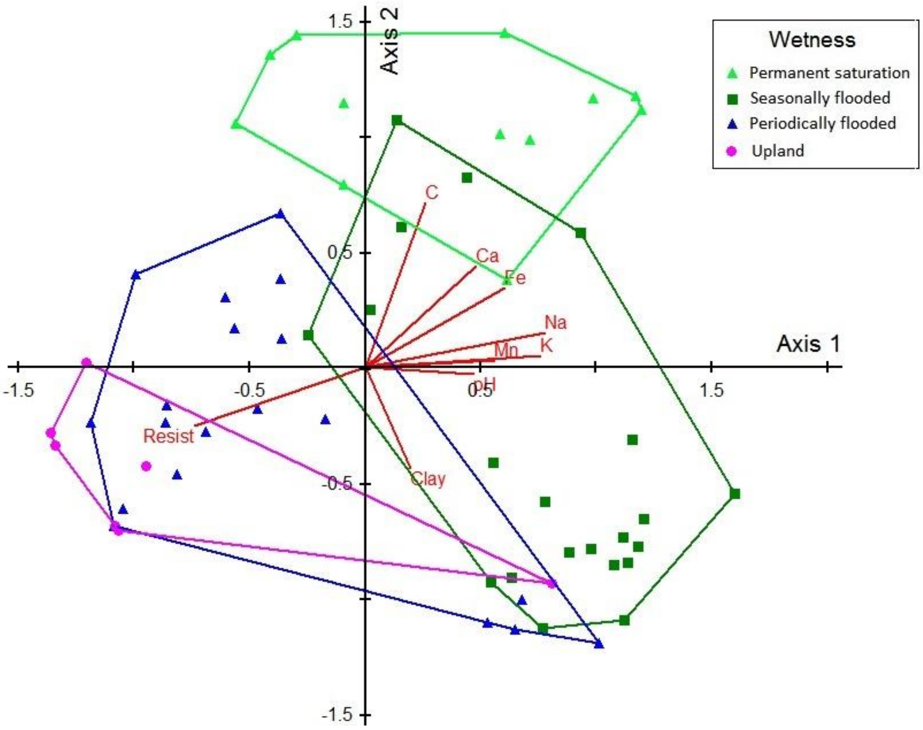

Figure 7.3. CCA results with the categorical variable wetness as an overlay. The Eigenvalues are 0.693 and 0.627 for Axis 1 and 2 respectively.

The Dufrêne & Legendre IV range from zero (no indication) to 100 (perfect indication). Perfect indication means that the presence of a species points to a particular group without error (with the current dataset, at least). The P-value gives an indication of statistical significance. Only significant species are included in the lists. Initially four tables were created to show the indicator species of the various zones, regardless of wetland type, as well as for each wetland type separately; and of the various wetland classes as per Table 7.1, regardless of wetland type, as well as for each wetland type separately. Investigation of these tables showed that the ISA for the various zones and wetness classes were not interpretable when it was not done per wetland type separately. The five wetland types are so different from each other that the ISA almost inevitably indicates species from only one specific wetland type to be indicative of a certain zone across all types. There were also much more occurrences of *no* indicator species being identified per zone or wetland class, where wetland type was not considered. Therefore only the two tables with indicator species of the various zones and wetness classes per wetland type were included below. This makes the tables longer with more information included, but is more explanatory.

Table 7.3 shows the indicator species, IV- and p-values per zone on the topographical gradient in each wetland type, and Table 7.4 the indicator species, IV- and p-values per wetness category in each wetland type. There are quite a large number of indicator species in most groups.

Table 7.3. Indicator species, IV- and p-values per zone in each wetland type.

Type	Zone	Indicator species	Species type	Indicator value (IV)	P-value	Nr. of plots
MS	1	*Phragmites australis*	Reed	90.6	0.0014	4
		Phyla nodiflora	Forb	84.5	0.0004	
MS	2	*Hibiscus diversifolius*	Forb	60	0.004	4
		Conyza canadensis	Forb	51.3	0.0008	
MS	3	*Dactyloctenium aegyptium*	Grass	49.7	0.019	4
MS	4	*Hyperthelia dissoluta*	Grass	66.7	0.0014	4
		Phyllanthus maderaspatensis	Forb	50	0.019	
		Eragrostis superba	Grass	33.3	0.044	
PP	1	*Ludwigia species*	Aquatic forb	100	0.0002	3
		Lemna gibba	Aquatic forb	63.6	0.016	
PP	2	*Ocimum americanum var. americanum*	Forb	60.6	0.019	3
		Eragrostis rotifer	Grass	56.4	0.019	
PP	3	*Spirostachys africana*	Tree	100	0.0002	3
		Panicum maximum	Grass	98.5	0.0002	
		Acacia karoo	Tree	92.8	0.0002	
		Euclea natalensis	Tree	66.7	0.01	
		Ziziphus mucronata	Tree	66.7	0.011	
		Euclea undulata	Tree	44.4	0.029	
		Hyphaene coriacea	Tree	30.8	0.031	
DP	1	*Pistia stratiotes*	Aquatic forb	66.7	0.009	3
DP	2	*Marsilea species*	Aquatic forb	92.9	0.0008	3
		Leersia hexandra	Grass	41.7	0.018	
		Echinochloa colona	Grass	40.2	0.045	
DP	3	*Cynodon dactylon*	Grass	29.2	0.036	3
PL	1	*Centella asiatica*	Forb	48.7	0.005	5
PL	2	*Eragrostis biflora*	Grass	60	0.012	5
PL	3	*Urochloa mossambicensis*	Grass	40	0.036	5
PL	4	*Eragrostis lappula*	Grass	50	0.025	2
IDD	1	*Blumea dregeanoides*	Forb	60	0.002	5
		Thelypteris interrupta	Forb	38.6	0.019	
IDD	2	-		-	-	5
IDD	3	-		-	-	5
IDD	4	*Hypoxis hemerocallidea*	Forb	66.7	0.007	3
		Raphionacme hirsuta	Forb	66.7	0.008	
		Digitaria eriantha	Grass	64	0.01	
		Stylosanthes fruticosa	Forb	62.5	0.0006	
		Themeda triandra	Grass	58.4	0.006	
		Cyperus obtusiflorus	Sedge	55.6	0.0002	

Table 7.4. Indicator species, IV- and p-values per wetness category in each wetland type.

Wetland Type	Wetness class	Indicator species	Plant type	Indicator value (IV)	P-value	Nr. of plots
MS	Permanent saturation	*Phragmites australis*	Reed	91.3	0.002	8
		Phyla nodiflora	Forb	83.6	0.002	
		Hydrocotyle bonariensis	Forb	54.7	0.008	
		Conyza canadensis	Forb	51.5	0.007	
		Hibiscus diversifolius	Forb	50	0.01	
		Flaveria bidentis	Forb	50	0.011	
		Ethulia conyzoides	Forb	50	0.012	
MS	Seasonally flooded	*Dactyloctenium aegyptium*	Grass	47.3	0.043	5
		Corchorus asplenifolius	Forb	38.6	0.025	
		Imperata cylindrica	Grass	34.5	0.043	
		Cymbopogon validus	Grass	32.1	0.045	
MS	Periodically flooded	*Hyperthelia dissoluta*	Grass	93	0.001	3
		Phyllanthus maderaspatensis	Forb	66.7	0.006	
		Litogyne gariepina	Forb	53.3	0.011	
		Eragrostis superba	Grass	51.3	0.015	
PP	Seasonally flooded	*Eragrostis rotifer*	Grass	50	0.011	6
		Ludwigia species	Aquatic forb	50	0.012	
PP	Periodically flooded	*Spirostachys africana*	Tree	100	0.0002	3
		Panicum maximum	Grass	98.5	0.0004	
		Acacia karroo	Tree	92.6	0.001	
DP	Seasonally flooded	*Echinochloa colona*	Grass	52.4	0.022	9
DP	Periodically flooded	*Cynodon dactylon*	Grass	56.3	0.008	2
		Justicia flava	Forb	56.2	0.012	
PL	Seasonally flooded	-		-	-	3
PL	Periodically flooded	-		-		11
PL	Upland	*Helichrysum kraussii*	Forb	59.7	0.008	2
IDD	Permanent saturation	*Rhynchospora holoschoenoides*	Sedge	57.1	0.008	7
		Blumea dregeanoides	Forb	42.9	0.015	
		Thelypteris interrupta	Forb	40.9	0.024	
IDD	Seasonally flooded	*Xyris capensis*	Forb	76.9	0.003	2
IDD	Periodically flooded	-		-	-	5
IDD	Upland	*Digitaria eriantha*	Grass	59.6	0.01	4
		Stylosanthes fruticosa	Forb	58.8	0.008	
		Raphionacme hirsuta	Forb	50	0.006	
		Hypoxis hemerocallidea	Forb	50	0.009	
		Cyperus obtusiflorus	Sedge	46	0.023	

Table 7.4 gives much more interpretable results than Table 7.3.

Phragmites australis and *Phyla nodiflora* were often encountered together in the peat in the Muzi Swamp. *P. australis* appears to be associated with peat on the MCP. It plays an important role in the stabilisation of the wetlands, and filtering of the water (Glen undated). No mention could be found in literature of *P. nodiflora* occurring in peat. However, it is an obligate species often found in slightly saline soil and salt marshes (Glen undated). Apart from *Flaveria bidentis* (an opportunistic, invasive species), all indicator species in the permanent saturation class in the Muzi Swamp are associated with marshy environments, some of them also with saline conditions.

The seasonally flooded area of the Muzi Swamp has more opportunistic species, although most species indicate wetness and often the boundaries of a wetland. *Dactyloctenium aegyptium*, thought to be an exotic, prefers sandy soil and often occurs where water collects (Van Oudtshoorn 2002). *Imperata cylindrica* is frequently found in seasonally, wet places in vleis, marshes, flooded areas, and river banks in poorly drained, moist, but supposedly in non-saline soil. According to Glen (undated), it is an indication of the outer most limits of a wetland and an important indicator of the transitional zone of the hydrosere and mesosere. The main indicator species of the periodically flooded area of the Muzi Swamp was found to be the grass *Hyperthelia dissoluta*.

There are two indicator species in the Tembe Park Perched Pans. *Ludwigia sp*. is an obligate, and emergent or free floating species, while *Eragrostis rotifer* is a facultative species occurring in sandy soils around vleis, pan edges and river beds, disturbed areas or dry watercourses. The thicket zone surrounding the pans is indicated by *Spirostachys africana, Acacia karroo*, and *Panicum maximum*.

In the Utilised Perched Pans *Echinochloa colona* is a facultative positive species which is associated with places where rainwater collects, such as in pans (Van Oudsthoorn 2002). It often occurs in trampled and overgrazed patches, especially on clay soils. *Cynodon dactylon* and *Justicia flava* are known to occur in a variety of habitats. *Cynodon dactylon* is classified as a facultative positive plant.

The Moist Grasslands only has indicator species in the upland positions surrounding the wetland: *Helichrysum kraussii* - a non-wetland species which often surrounds wetland areas (based on personal observations).

Rhynchospora holoschoenoides and *Thelypteris interrupta* are both regarded as diagnostic and constant species in the Interdunal Depressions. This was also found by Pretorius (2011). *Rhynchospora holoschoenoides* is known to occur in wet sandy places, commonly in marshes (Van Ginkel et al. 2011) which explains its absence in the clayey wetland types and the dry PL Type. According to Glen (undated) *Thelypteris interrupta* always occurs in full sun in marshes, and is dependent on continuously wet soils or surface water.

Xyris capensis is indicative of the seasonally flooded areas of the IDD Type, and is generally known to occur along the edge of water sources (Glen undated). It was only encountered in the sandy IDD Type, and here also not in all the seasonally flooded areas. There were no indicator species in the periodically flooded areas. There are a variety of indicator species of the Upland sites of the IDD Type. *Digitaria eriantha* is known to occur close to wetland areas but not in wetlands (Van Oudtshoorn 2002; Glen undated). The rest of the indicator species all share a preference to grassland habitat (Pooley 1998).

7.2.2 Weighted Averaging

Day et al. (2010) compiled a list of existing literature and publications regarding the distribution and/or habitat types of wetland plants in different regions of South Africa. These publications are aimed primarily at the provision of a list of wetland plants that can be used as indicator species of general wetland conditions. In order to apply the categories a list of plant species which have been assigned an indicator status is required. Most studies in the USA use the 'National list of plant species that occur in wetlands' of Reed (1988). In South Africa such a published list is not available. For this study the 'Annotated checklist of the wetland flora of southern Africa' (Glen unpublished) was used. This list was compared to the indicator list of wetland plant species of South Africa developed by Hoare (2007), but the list of Glen (unpublished) was found to be more recent and complete.

Based on the Weighted Average (WA) scores, all plots (plant communities) were categorised as indicated in Table 4.4. Table 7.5 indicates the average WA scores and standard deviation for the communities per wetland type, as well as the number of communities that constitute the categories per wetland type.

Table 7.5. Descriptive statistics to indicate prevalence of communities to certain categories and wetland types.

		MS Type	PP Type	DP Type	PL Type	IDD Type
Wetland (<2)	**Average WA score**	1.71±0.17	1.46±0.53	1.68±0.34	1.96	1.49±0.30
	Number of sites (%) per Type	44%	44%	58%	6%	33%
Good probability of being a wetland (2.0 - 2.5)	**Average WA score**	2.28±0.19	-	2.43	2.18±0.12	2.25±0.18
	Number of sites (%) per Type	25%	-	8%	29%	22%
Inconclusive (2.5 - 3.5)	**Average WA score**	2.76	3.29	3.15±0.34	2.98±0.31	3.03±0.41
	Number of sites (%) per Type	6%	11%	33%	29%	17%
Good probability of being an upland site (3.5 - 4)	**Average WA score**	-	-	-	3.73± 0.23	-
	Number of sites (%) per Type	-	-	-	18%	-
Upland (>4)	**Average WA score**	4.72±0.15	4.34±0.24	-	4.3±0.32	4.64±0.21
	Number of sites (%) per Type	25%	44%	-	18%	28%

Figure 7.4 gives an indication of the relationship between the various plot WA scores, the separation into the Plant Indicator Status Categories (coloured blocks) (as per Table 4.3), and the separation based on the criteria to classify as a wetland or not (dotted lines) (Table 4.5).

The majority of the plots fall within the facultative+ wetland- and upland categories. Very few plots are actually classified as obligate wetland sites. These consist of plots from the bottomland zones from the Tembe Park Perched Pans (PP Type), Utilised Perched Pans (DP Type), and Interdunal Depressions (IDD Type). The bottomland zones of the Muzi Swamp are more dominated by facultative+ species, but still fall within the wetland category as per Table 4.5. Some of the upland plots of the Moist Grasslands occur in the facultative- sites category. The Upland category contains a lot of plots - all from the upland sites of the various wetland types (except for the Utilised Perched Pans, which is conspicuously missing).

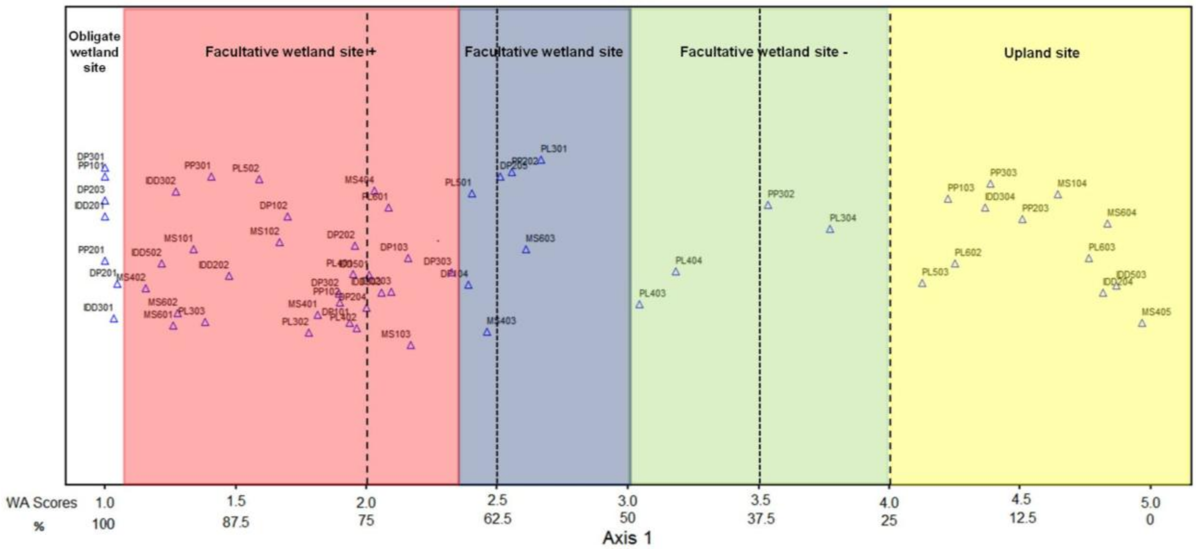

Figure 7.4. The Weighted Averaging results obtained from the multivariate software PC-ORD. The coloured blocks indicate the separation of the various Plant Indicator Status Categories, based on Table 4.3 (the associated percentages are indicated on the x-axis). The WA score of each plot indicates the dominance of species composition from a specific Plant Indicator Status Category. Yellow = the upland sites; green = the facultative– wetland sites; blue = the facultative sites; red = facultative+ wetland sites; and white = the obligate wetland sites. The dashed lines indicate the boundaries of the different criteria classes of WA scores (Table 4.5), which categorize the various plots as a wetland, probable wetland, inconclusive, probable upland, and upland (the associated WA scores are shown on the x-axis).

The WA scores were also calculated per wetland type to determine whether certain wetland types are more dominated by wetland species than other wetland types (Figure 7.5). There are no differences in the distribution of WA scores between the different wetland types; meaning that no wetland type is 'more wetland-like' than another. However, the Utilised Perched Pans are more dominated by wetland species than the other wetland types, and the Moist Grasslands has an absence of obligate wetland species.

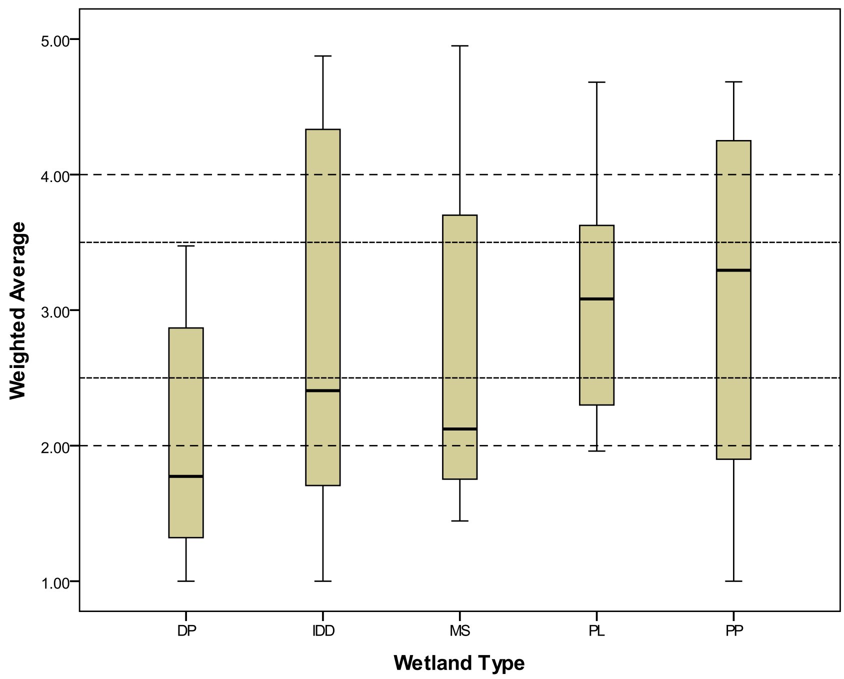

Figure 7.5. The WA scores per wetland type. The dashed lines indicate the boundaries of the different classes of WA scores (Table 4.5).

Figure 7.6 illustrates the distribution of WA scores along the topographical gradient per wetland type. Although there is a clear trend from a concentration of wetland species in the bottomland zones (zones 1 and 2) to more dryland species in Zone 4, it is obvious that the wetland types should be considered separately, and that a single model of species turnover over a topographical gradient does not fit all wetland types.

The Muzi Swamp is dominated by obligate wetland species in Zone 1, and a higher WA score in Zone 2 which already indicates the closer proximity to the edge of the peatland. Zone 3 is dominated by more wet than dry species, while Zone 4 is undoubtedly an upland zone. There is a sharp distinction between Zones 3 and 4 of the Muzi Swamp, which indicates a complete species turnover from the one zone to the next. Within the Interdunal Depressions, also a peatland, the bottomland zones are dominated by wet communities, and Zone 4 by dry communities. Zone 3, however, is very variable and can have both wet or dry plant communities. It is located on the dune footslope, and can be regarded as a transition zone between the peatland and the upland.

The clay-rich Tembe Park Perched Pans has a clear trend from wet species in Zone 1 to dryland species in Zone 3 (there are only three zones in this wetland type). Zone 2 is clearly a transition zone having occurrences of both obligate wetland communities as well as dryland communities. It is therefore inconclusive to define as a wetland or not, based solely on vegetation. The clay-rich Utilised Perched Pans also have only three zones, but are considerably different from the Tembe Park Perched Pans in terms of WA scores. Although Zone 1 is dominated by wet communities as expected, Zone 3 is classified as inconclusive with regards to being a wetland or an upland zone. This zone was often dominated by *Cynodon dactylon,* which is classified as a Facultative + species. In the Utilised Perched Pans, however, this species occurred on the ridges surrounding the pans. The vegetation therefore cannot give a clear indication whether this is a wetland zone or not. Based on the dominant species it could be wet, but based on topography it is most probably an upland zone.

Within the Moist Grasslands there is a clear lack of obligate wetland species in the centre of the wetland. However, most of the plots still have a good probability of being a wetland (WA = 2.0 – 2.5). Zone 2 also has a good probability of being a wetland, but leans a bit more towards the inconclusive category (WA = 2.5 – 3.5). Zone 3 is mostly inconclusive, while Zone 4 has a good probability of being an upland site.

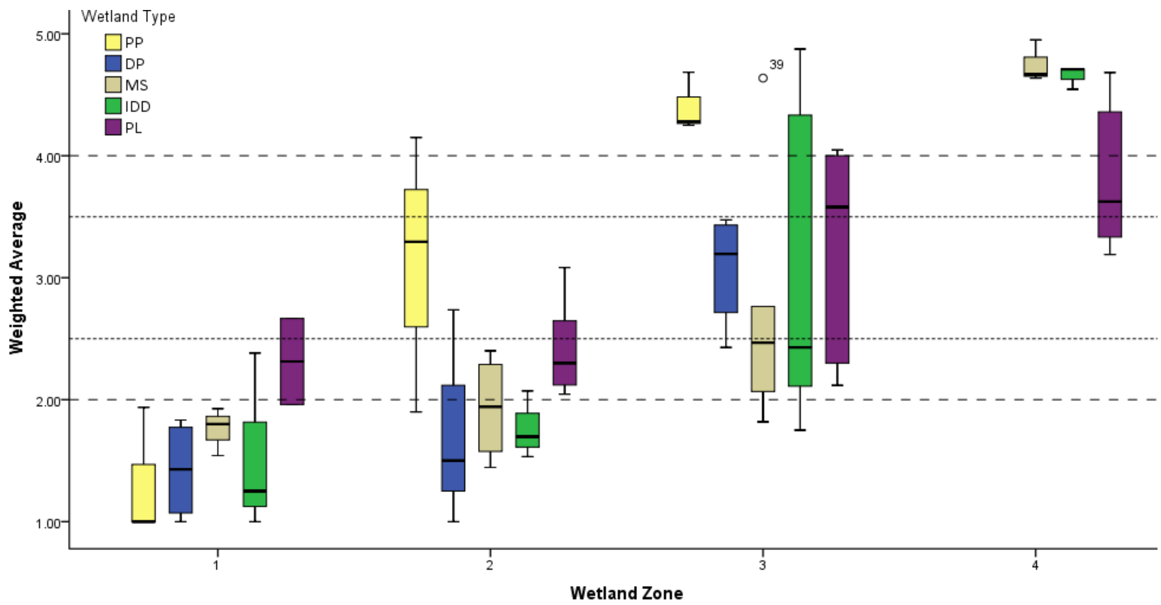

Figure 7.6. The distribution of WA scores along the topographical gradient per wetland type. The dashed lines indicate the boundaries of the different classes of WA scores (Table 4.5). Note that the DP and PP Types have only 3 zones.

The same wetness classes of Table 7.1 were applied to the WA data. Because of the unequal representation of plots in the various wetness classes, and also since the wetness classes are comparable across wetland types (which was not the case for the wetland zones), the wetland types were combined in this analyses. Figure 7.7 emphasises that the WA scores - i.e. plant hydrophilia - do not correlate perfectly with the defined wetness classes (e.g. it would be expected that all plots classifying as 'Upland' would have a score of *at least* higher than WA = 3, but this is not the case).

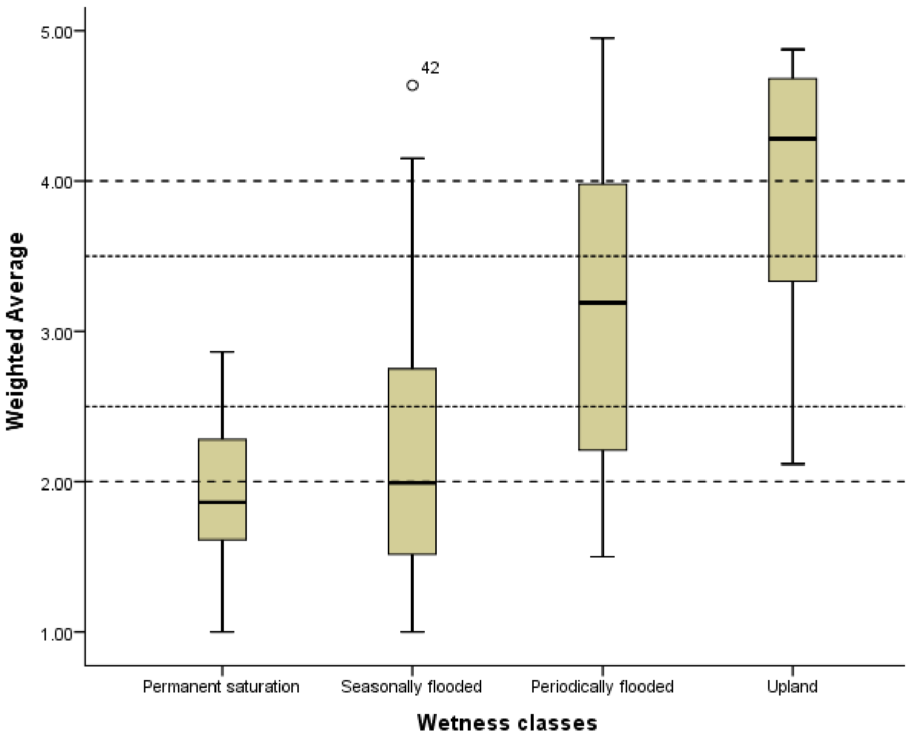

Figure 7.7. The distribution of WA scores according to the wetness classes defined in Table 7.1 per wetland type. The dashed lines indicate the boundaries of the different classes of WA scores (Table 4.5).

7.3 Discussion

7.3.1 The relationship between vegetation and soil properties

The ordination results are very similar to what was found by Sieben (2014). Although an affiliation was found with clay content, the most clearly contrasting communities were those low in clay contents and electrical conductivity on coastal sands.

The gradient from the positive Axis 2 to the negative Axis 1 is highly correlated to the relevés from the Muzi Swamp, Moist Grasslands, and Interdunal Depressions. The positive Axis 2 is dominated by carbon content and resultant high cations, Fe and Mn; the negative Axis 1 by relevés that are mainly sandy in nature, have high resistance, and are poor in the above-mentioned soil properties. This pattern is clearly associated with wetness, and therefore confirms the wetness classes defined in Table 7.1. It is also clear that the wetland types dominated by only a clay substrate (i.e. the clay perched pans) have no apparent wetness gradient down the topographical slope (or the small gradient is obscured in the ordination diagrams).

Figure 7.3 illustrates that although wetness is a strong gradient, strictly defined zones of wetness using vegetation and soil ordinations are not viable. However, it is apparent that zones of permanent wetness are distinctly removed from the periodically flooded- and upland zones. Similarly, zones of seasonal flooding are distinctly removed from the upland zones.

As expected soil organic carbon is strongly associated with the permanently saturated wetness class, and also to a lesser degree with seasonally flooded plots not on a clay substrate. For different reasons both clay and organic matter can be seen as the active fraction of soil. The smaller particles of clay have colloidal properties, and due to their extremely small size, have a tremendous surface area per unit mass. Organic carbon also has charged surfaces. As a result both clay and carbon attract positive and negative ions, and are therefore the fraction with most chemical and physical activity (Brady & Weil 2007). The association of Fe, Mn, the cations and pH with both carbon and clay is therefore expected. Resistance is the most influential variable, and is associated with those plots which are periodically flooded or well-drained, and located on sandy substrates. High resistance indicates an absence of salts, which is expected in these sandy locations.

The results of the ISA were easier to interpret when they were related to the various defined wetness classes, instead of the wetland zones down the topographical gradient. This is probably because the wetland zones used in this study were defined when a major change in vegetation composition down the topographical slope was encountered. This however, often included communities of the same wetness classes. The ISA then indicated species actually indicative of similar conditions. The results of the ISA per wetness class correlated well with the various wetland conditions. Not all wetness classes contained indicator species. The list of indicator species was shortened to only contain those key species that are easily observable in the field and could be used as fast field indicators (Table 7.6):

Table 7.6. Key Indicator species in each wetland type for most of the wetness classes.

Wetland Type	Wetness class	Indicator species	Wetland Type	Wetness class	Indicator species
Muzi Swamp	Permanent saturation	*Phragmites australis*	**Utilised Perched Pans**	Seasonally flooded	*Echinochloa colona*
		Phyla nodiflora		Periodically flooded	*Cynodon dactylon*
	Seasonally flooded	*Dactyloctenium aegyptium*			*Justicia flava*
		Imperata cylindrica	**Moist Grasslands**	Upland	*Helichrysum kraussii*
	Periodically flooded	*Hyperthelia dissoluta*	**Interdunal Depressions**	Permanent saturation	*Rhynchospora holoschoenoides*
		Eragrostis superba			*Thelypteris interrupta*
Tembe Park Perched Pans	Seasonally flooded	*Eragrostis rotifer*		Seasonally flooded	*Xyris capensis*
		Ludwigia species		Upland	*Digitaria eriantha*
	Periodically flooded	*Spirostachys africana*			*Cyperus obtusiflorus*
		Panicum maximum			*Themeda triandra*
		Acacia karroo			

Many of the indicator species in the peat of the Muzi Swamp here are associated with marshy and saline conditions, and the Muzi Swamp with its high pH and cation-richness is therefore a perfect habitat. The seasonally flooded Muzi Swamp had more opportunistic species, although most species indicate wetness and often the boundaries of a wetland. Based on the vegetation, Pretorius (2011) regards the communities with the dominant and diagnostic species *Hyperthelia dissoluta* in the

Acacia karroo–Hyperthelia dissoluta sub-community in the Muzi Swamp as terrestrial. However, the soil data indicate that this area is periodically flooded, or at least dominated by a hillslope seep.

The Tembe Park Perched Pans were classified as seasonally flooded based on literature (Matthews et al. 2007) as well as field observations. The seasonal open water in the pans is dominated by *Ludwigia sp*. while *E. rotifer* is an indicator during dry months, or the areas surrounding the open water. The ISA of the drier areas of the PP Type confirms the results of the WA analyses: that the vegetation and the wetness classes do not correspond perfectly. The thicket zone surrounding the pans was classified as periodically flooded due to soil wetness indicators. However, the indicator species *Spirostachys africana* and *Acacia karroo*, and the grass *Panicum maximum* rather indicate terrestrial conditions.

As with the Tembe Park Perched Pans, the Utilised Perched Pans are also a seasonally flooded clayey system. Although *Echinochloa colona* also occurred in the Tembe Park Perched Pans, it was not as dominant in the seasonally flooded areas as in the Utilised Perched Pans. Another indicator species is *Cynodon dactylon;* however this species is very variable on the MCP. Although it is classified as a facultative positive plant, it has been found in seasonal soils, on the dunes surrounding these clay pans on the MCP, as well as around peatlands on the MCP where it prefers the moist sandy and fertile soil.

The only indicator species *Helichrysum kraussii* in the Moist Grasslands is very often encountered on the sandy soils close to wetlands on the MCP, and is often used as a rapid visual indicator of wetland boundaries by wetland specialists. The permanently flooded areas of the IDD Type are indicated by the peatland species *Rhynchospora holoschoenoides* and *Thelypteris interrupta*; while *Xyris capensis* is indicative of the seasonally flooded areas of the Interdunal Depressions. The indicator species of the Upland areas all share a preference to grassland habitat.

7.3.2 Weighted Averaging

While it was found that Indicator Species Analysis (ISA) was more effective using the defined wetness classes, the Weighted Averaging (WA) approach did not give very satisfactory results when applying the wetness classes to it. It was expected that at least the sites categorised as 'uplands' would be significantly different from the other categories in terms of the WA scores. This is not the case, although there is a gradient of change from permanent saturation to the uplands (Figure 7.6). It therefore stands to reason that either: 1) The WA approach is not very successful, 2) the wetness classes were not assigned perfectly objectively to each site, or 3) the indicators of both the plant and soil do not correlate well. It is suspected that it is rather the latter in this case. In both the Muzi Swamp and Tembe Park Perched Pans the sites which are indicated as upland sites (as per the vegetation), are still regarded as periodically flooded soil in terms of the sites' soil characteristics. Similarly, in the Interdunal Depressions and Moist Grasslands the soil indicates few signs of wetness at all (refer to Chapter 5), and is in fact regarded as a profile of pure sand with very little chemical and physical alteration (e.g. Namib soil form); yet the plants indicate that the site may be a wetland (WA score varying between 2.43 – 4.88). However, this is not seen as an error of the plant indicator list and the WA process, but rather as a lack of proper understanding of the relationship between vegetation and soil, and its relationship to fluctuating water levels or saturated conditions.

With the WA approach it is important to note that the criteria classes for a site to classify as a wetland or not, are not the same as the Plant Indicator Status Categories. Although a site might not be dominated by obligate wetland plants, it does not mean that it is not a wetland. For example, the plots that fall into the obligate wetland site category (Figure 7.4) are located there purely because the majority of plants in those plots are regarded as obligate wetland plants. Additionally, an 'obligate wetland' does not need permanent saturation. The few sites from the bottomland zones of the Tembe Park Perched Pans, Utilised Perched Pans, and Interdunal Depressions are 'obligate wetland sites' (Figure 7.4), directly as a result of the presence of free water. Theoretically all wetlands should have at least a few obligate wetland species or be totally dominated by a single species. If any species which classify as facultative species are found in a site, then the site may possibly be a wetland. However, if mainly upland species are present and dominant, then the site could not be classified as a wetland. It is for this reason that, whether permanently or temporarily saturated, one wetland is not necessarily more 'wetland-like' than another, in terms of species hydrophilia.

All the wetland types had plots which classified as wetland sites (WA < 2; Table 4.5), even the very temporarily wet Moist Grasslands. The fact that so many of the plots fell within the WA upland category while it was argued in Section 7.2.1 that the Upland wetness class was under-sampled, proves that vegetation much more readily indicates non-wetland conditions despite evidence of wetland conditions in the soil. This is not to say that the vegetation indicator is incorrect, but rather that the dynamic relationship between soil and vegetation indicators still leaves a lot for investigation.

Surprisingly, none of the plots from the Muzi Swamp, a peatland similar to the Interdunal Depressions, was dominated enough by obligate wetland plants to classify it into the obligate category. This probably indicates that the Muzi Swamp is a much drier peatland than the Interdunal Depressions peatlands - possibly due to it being located on a higher elevation much further from the coast with a subsequent lower sea-level pressure on the ground water table. The Utilised Perched Pans have no plots in the WA Upland category, and according to Figure 7.5 are more dominated by wetland species than the other wetland types.

The WA approach does lend itself to straightforward wetland boundary delineation, strictly in terms of vegetation down a topographical slope. For example, the Muzi Swamp has a sharp distinction between Zone 3 (inconclusive in terms of wetland presence) and Zone 4 (definitely upland) (Figure 7.6), which can be regarded as the boundary between wetland and non-wetland conditions in terms of vegetation. The Interdunal Depressions behave in a very similar manner, except that Zone 3 (located on the dune footslope), can be regarded as a transition zone between the peatland and the upland. Solely based on the vegetation grouping this zone appears to lean more towards being an upland site, although it is mostly inconclusive (Figure 7.6). It probably differs between various interdunal peatlands, and depending on the slope, this zone could be either more 'wetland-like' or more 'upland-like'.

The clear trend from wet species in Zone 1 to dryland species in Zone 3 in the clay-rich PP Type is in contrast to both the plant- and soil ordinations (Figure 7.3, and Figure 6.1), which showed no wetness gradient at all; although it could have been obscured by the much more significant wetness gradient in the other wetland types. The WA scores of the DP Type indicate once again, that the soil and vegetation indicators do not correlate well within the clay rich wetlands.

The WA scores confirm the temporary nature of the Moist Grasslands. The lack of obligate wetland species indicates that few species here require saturation for their life cycle.

7.4 Conclusion

According to DWAF (2005), the vegetation indicator as described in the delineation manual is relatively region specific and needs refinement over time. Since wetland species are usually found along an environmental gradient (Reed 1988), and soil properties influence the distribution of wetland plant species (Reddy & DeLaune 2008), more approaches can be used to understand vegetation in wetlands, than just those recommended by DWAF (2005). The aim of this chapter was to understand vegetation composition and plants as an indicator of wetland conditions better, by 1) Investigating the relationship between vegetation and soil; 2) Considering Indicator Species as wetland indicators; and 3) Applying a relatively under-utilized approach called Weighted Averaging to determine whether a site is a wetland, based on the indicator status of plant species.

The ordination results highlighted two environmental gradients, which agree with the gradients of Charman (2002).

1. The wetness gradient. This is the strongest gradient, and is supported by the soil properties carbon and resistance. Soil organic carbon is strongly associated with permanently saturated soil (e.g. peatlands), whereas high resistance is associated with freely drained sandy soils.

2. The productivity gradient. The soil cations, iron, manganese, and pH are all associated with both organic carbon, and to a lesser degree clay, on the positive Axis 1. The productivity of the soil (and therefore the plants) decreases to the negative Axis 1 which is dominated by freely drained sandy soils characterised by high resistance (low electrical conductivity).

However, even though wetness is a strong gradient, strictly defined zones of wetness are not viable in the study area in terms of vegetation composition. Especially the seasonally flooded zones are very transitory, and therefore very variable, even within wetlands of the same wetland type. However, the upland zones are usually very characteristic.

The Indicator Species Analysis confirmed that it is possible to use wetland plants as indicators for environmental conditions (Sieben 2014). These species are useful as fast field indicators to ascertain wetness classes when working in these specific wetland types. Wetland types should always be considered separately due to the high variation between types. Not all wetness classes contained indicator species; however, this could be corrected with more intensive sampling. In some cases, such as in the Tembe Park- and Utilised Perched Pans, vegetation was once again shown to not correlate perfectly with the soil indicators. This is also confirmed by the Weighted Averaging results, where the WA scores did not always correlate well with what was regarded as 'upland' wetness class. This is mostly not regarded as a limitation of the WA approach, but rather as a lack of proper understanding of the relationship between vegetation, soil, and soil saturation. It would seem as if vegetation communities indicate fluctuating environmental conditions much more readily than the soil.

Overall the WA approach appears to be a valuable and useful tool to apply in wetland science, and especially in delineation practices. Based on Figure 7.6 most wetland types show a clear shift in WA scores from the bottomland- to the upland zones on the topographical gradient, which also correlate relatively well with the recommended criteria for classification as a wetland or not (Table 4.5). Should this be applied thoughtfully, it can go far to determine zones of wetland vegetation. It should, however, be noted that the WA approach functions on the basis of probability, and since vegetation has been shown to be very dynamic and variable, the vegetation indicator should never be used as the only indicator, but should be interpreted at the hand of supplementary environmental data. Because there is currently not a complete published list of wetland plant species and their indicator statuses for the whole country, weighted averaging as a method of evaluating wetlands are not used in South Africa. However, this study indicates the value of this method, and therefore emphasises the need for this list by Glen (undated) to be published.

Chapter 8
SOIL COLOUR AS INDICATOR OF SOIL ORGANIC CARBON AND WETLAND BOUNDARIES ON THE MCP

8.1 Introduction

It is widely accepted that soil colour has no effect on the behaviour and use of soils, and is mainly used to give an indication of the status of other soil parameters and conditions (Melville & Atkinson 1985). The current main use of soil colour is in soil profile and -horizon classification methodologies. Literature further suggests that there is some relationship between soil organic carbon (SOC) and soil colour (Wills et al. 2007, Viscarra Rossel et al. 2006, Konen et al. 2003, Schulze, et al. 1993, Renger et al. 1987, Steinhardt & Franzmeier 1979). Whether a relationship between SOC and soil colour exists in wetlands occurring on the sandy coastal aquifers of the Maputaland Coastal Plain (MCP) has not been established yet. However, a quantifiable relationship might go a long way into determining wetland, and wetland wetness zone boundaries, by rapid, field-based appraisal.

This chapter addresses two research questions:

1. Does organic carbon content correlate with soil colour on the MCP?
2. If so, can topsoil colour be used for wetland zone delineation?

The objectives of the chapter are therefore to:

- Determine whether soil colour correlates with soil organic carbon content in wetlands by testing various approaches on the data.
- Determine whether a topsoil colour gradient down a slope into a wetland can be an indicator for wetland zone boundaries, by indicating how the organic carbon content changes.

8.2 The correlation between organic carbon and soil colour

The following Munsell parameters and indices from various authors were correlated with SOC:

- Dry Value
- Dry Hue
- Dry Chroma
- Wet Value
- Wet Hue
- Wet Chroma
- Value (Dry - Wet)
- Value (Dry + Wet)

- Mokma & Cremeens (1991) index: Dry colours
- Mokma & Cremeens (1991) index: Wet colours
- Evans & Franzmeier (1988) index: Dry colours
- Evans & Franzmeier (1988) index: Wet colours
- Godlove (1951) and Melville & Atkinson (1985) index: colour difference between moist and dry
- Godlove (1951) and Melville & Atkinson (1985) index: Dry colour relative to reference colour

Munsell parameter indices from Van Huyssteen et al. (1997):

- H(EF) + V (dry)
- H(EF) + V (wet)
- H(EF) + V + C (dry)
- H(EF) + V + C (wet)
- V + C (dry)
- V + C (wet)
- H(EF) dry + V dry + H(EF) wet + V wet
- V dry + C dry + V wet + C wet
- V dry * V wet
- (H(EF)dry + V dry)*(H(EF) wet + V wet)
- (V dry + C dry)*(V wet + C wet)
- H(EF) dry + V dry + C dry + H(EF) wet + V wet + C wet
- (H(EF)dry + V dry + C dry)*(H(EF) wet + V wet + C wet)

The data were also divided into the three substrate groups (Pretorius 2011, Soil Classification Working Group 1991):

- High Organic soils are substrates where soil organic carbon > 10%,
- Clay soils are substrates where clay > 10% clay,
- Sandy soils are substrates where sand < 10% clay.

The r^2 values for the listed correlations above are given in Table 8.1. The r^2 values for the correlations from the three texture groups are given in Table 8.2. The best fitting regression curve for all the correlations was the polynomial regression curve. The scatter plot diagrams for all the correlations where $r^2 > 0.3$ are indicated in Figure 8.2.

Table 8.1. The correlation (r^2) of various Munsell colour parameters with SOC, in decreasing order, where H(EF) = Hue, as adapted by Evans & Franzmeier (1988); V = Value; and C = Chroma.

Munsell parameter	r^2
Godlove (1951) and Melville & Atkinson (1985) index: Dry colour relative to reference colour *(hereafter referred to as the M&A Index)*	0.39
Dry Value	0.38
V + C (dry)	0.38
V dry + V wet	0.38
V dry * V wet	0.35
V dry + C dry + V wet + C wet	0.33
(V dry + C dry)*(V wet + C wet)	0.29
V + C (wet)	0.24
Wet Value	0.22
Value (Dry - Wet)	0.20
Godlove (1951) and Melville & Atkinson (1985) index: colour difference between moist & dry	0.19
Dry Chroma	0.15
Wet Chroma	0.15
H(EF) dry + V dry + C dry + H(EF) wet + V wet + C wet	0.11
(H(EF)dry + V dry + C dry)*(H(EF) wet + V wet + C wet)	0.11
H(EF) + V + C (wet)	0.10
H(EF) + V + C (dry)	0.09
Evans & Franzmeier (1988) index: Dry colours	0.08
(H(EF)dry + V dry)*(H(EF) wet + V wet)	0.07
H(EF) dry + V dry + H(EF) wet + V wet	0.06
H(EF) + V (wet)	0.06
H(EF) + V (dry)	0.04
Dry Hue	0.04
Evans & Franzmeier (1988) index: Wet colours	0.03
Mokma & Cremeens (1991) index: Wet colours	0.02
Mokma & Cremeens (1991) index: Dry colours	0.02
Wet Hue	0.004

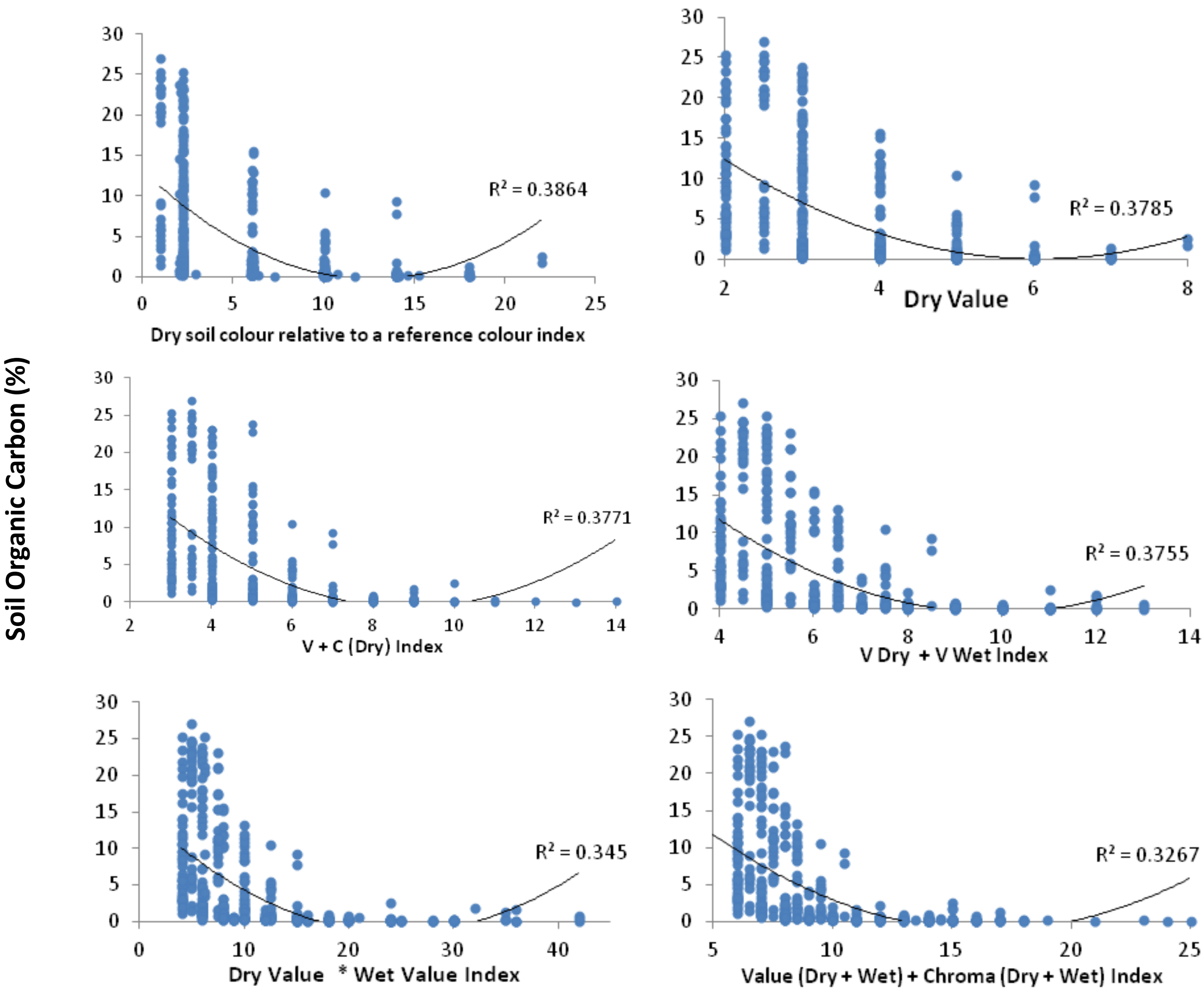

Figure 8.1. Scatter plot diagrams for the correlations with various Munsell parameters and indices above r^2 = 0.30.

Munsell Value, combined in various fashions with other parameters and in different wetness states (moist or dry), correlated the best with SOC. It was conspicuous that the dry colour correlations, and even dry and wet colour combinations (Dry + Wet and Dry * Wet), also provided much better results than the wet colour correlations. As was found by Konen et al. (2003), Munsell Chroma influences the correlation with SOC somewhat. In contrast, Munsell Hue correlated very weakly, and also seemed to lower the correlation value significantly whenever it was added into an index. The colour indices of Evans & Franzmeier (1988) and Mokma & Cremeens (1991) did not correlate well with SOC, even though the incorporation of Chroma and Hue indicated good correlations to the degree of wetness and duration of water tables. A change in the Hue of a soil was often associated with the presence of soil moisture. A change in soil organic matter, however, does not affect Hue as much. Munsell Value, on the other hand, was associated with a change in organic matter content in a soil. This seemed to be consistent for most of the studies discussed in the literature review, regardless of soil type, climate, geographic setting, or texture.

Table 8.2. The r^2 values for the correlations from the three texture groups.

Munsell parameter	r^2
High Organic Carbon	
Dry Value	0.235
Wet Value	0.029
Sandy	
Dry Value	0.574
Wet Value	0.207
Clayey	
Dry Value	0.497
Wet Value	0.396

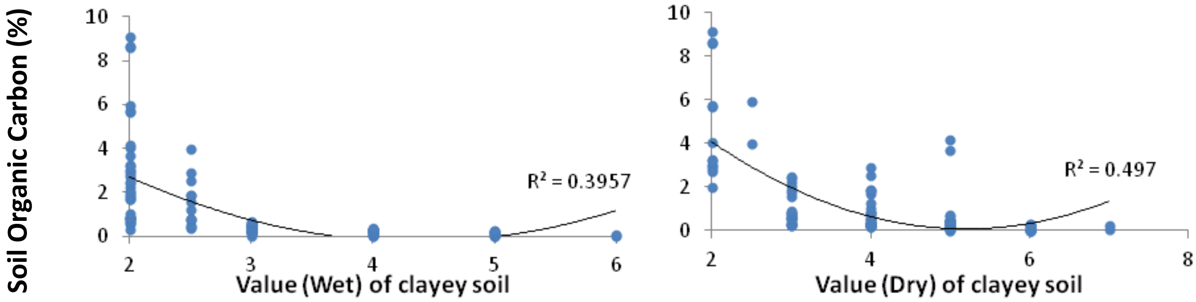

Figure 8.2. Scatter plot diagrams to indicate the relationship between Value and SOC within the three texture classes above r^2 = 0.3.

The correlations between colour and SOC were overall much higher when the soil was divided into their respective substrate types. This confirmed the statement by Steinhardt & Franzmeier (1979) and Franzmeier (1988) that colour-SOC relationships should be applied within a soil texture class and land use. Dry Value again had the highest correlation in the sandy and clayey soil. High organic soils fared weakly, and no distinct patterns arose from the data. Franzmeier (1988) may offer an explanation for this by stating in his study that darkly coloured, poorly drained soils can result in a large deviation from the mean, while lighter coloured, poorly and freely drained soils give better correlations. This implies that the degree of waterlogging within a texture class may also influence the correlation of colour and SOC content, and was substantiated by the lower r^2 in wet soils of all textural classes (Table 8.2).

The above results indicated a distinct scattered pattern of data points. Although a relationship between most indices and SOC could be observed, only a small proportion of the variations was accounted for with curvilinear relationships. It was clear that a relationship between soil colour and SOC did exist, especially when taking the Munsell Value into account. This relationship, however, was not a direct one, and it was unclear what the other influencing factors were. If soil colour was affected by more than one factor and there was an interaction between these multiple factors, quantile regression models might be useful. Applying segmented quantile regressions to this data will elucidate the relationship between soil colour and SOC by indicating maximal and minimal areas of occurrence and defining colour limits. Segmented quantile regressions were applied to the relationships indicated in Table 8.1, based on the correlation value and the shape of Figure 4.13.

With most of the indices a polynomial regression curve was the best fit to the data. Polynomial curves assume that data will decrease, reach a low- or turning point, and increase again. For this data set a polynomial curve will not reflect the real conditions in nature, as it will expect of the colour index value to increase again with an increase in carbon content. Since this will never be the case, the second best fit to data was selected, which was either a power-, or logarithmic curve, and in one case a linear curve.

Segmented Quantile regressions indicated distinct relational envelopes as delineated by the 0.9 and 0.1 quantiles for most of the Munsell parameters and indices tested (Figure 8.3). Table 8.3 indicates a number of noteworthy deductions. Firstly, the Segmented Quantile regression will be high if the original correlation was high. However, the correlations which obtained the highest r^2 values did not necessarily obtain the highest r^2 values when Segmented Quantile regressions were applied. Secondly, distinct boundaries could be defined where conclusions of predictably minimal and potentially maximal distribution of data could be made. Numerous colour indices had ranges in which SOC content was predictably minimal, but no index had a range in which SOC content was predictably maximal. A general conclusion of this nature would probably be difficult to reach without such a large dataset (Mills et al. 2006).

Using the equations of each of the various colour indices the exact threshold values for potentially maximal and predictably minimal SOC contents were determined (Table 8.3).

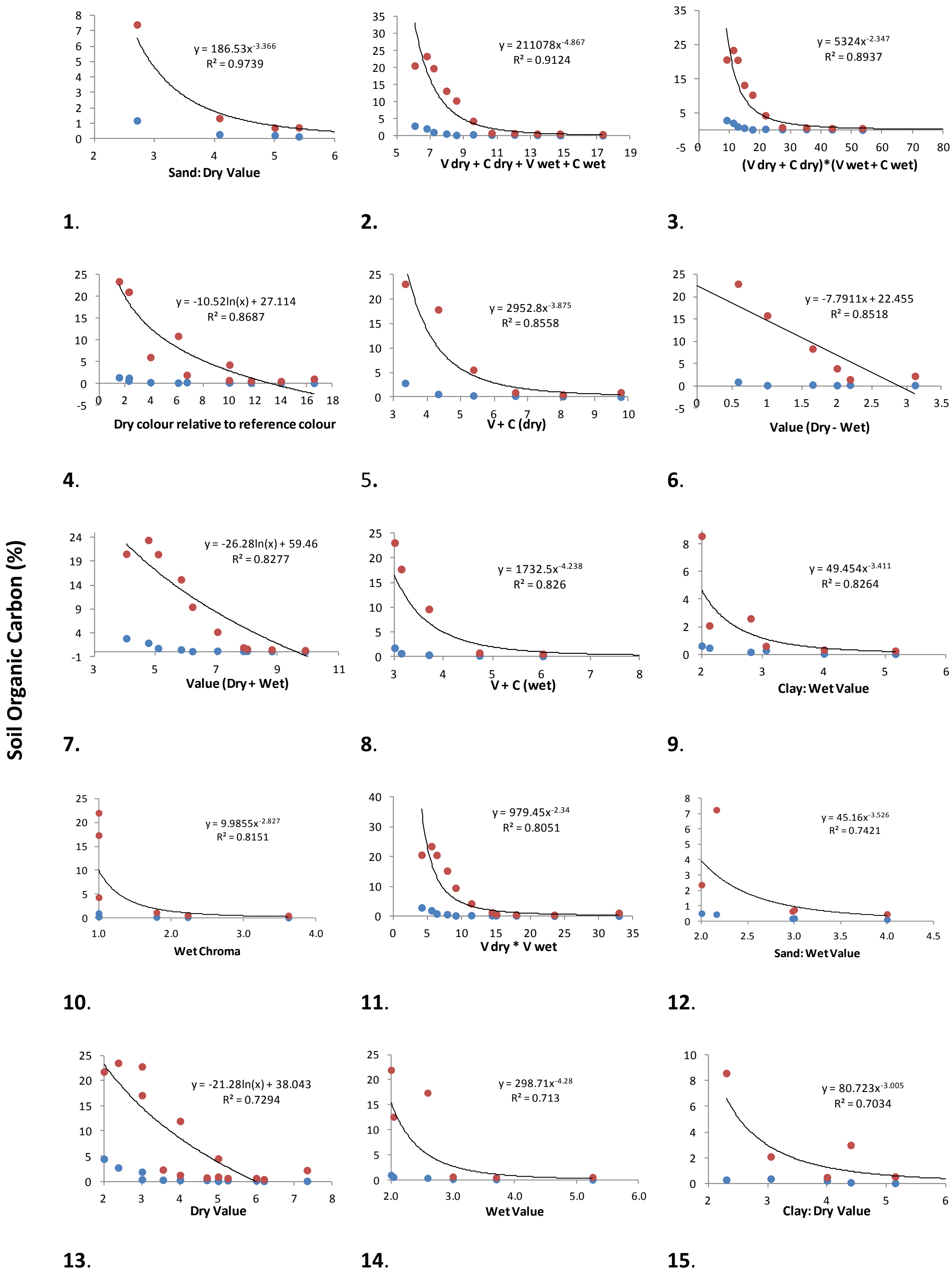

Figure 8.3. Relational envelopes derived from segmented quantile regression depicting the relationships between various Munsell parameters and indices (within the full dataset as well as within the different texture groups), above $r^2 > 0.7$. The 0.9 quantile is indicated in red, and the 0.1 quantile in blue. Numbers 1 – 15 relates to Table 8.3 and Table 8.4.

Table 8.3. The segmented percentile regression correlation values of various Munsell colour parameters with SOC (within the broad dataset as well as within the different texture groups), sorted according to r^2 values, where V = Value; and C = Chroma. Also indicated are the r^2 values as per Table 8.1 for comparative purposes (shaded), the Segmented Quantile regression equations, as well as the points on the x-axis where SOC content is a minimum for each individual index.

	Munsell parameter	r^2 (Table 8.1)	Segmented Quantile regression r^2	Points on the x-axis where SOC content is a minimum
1.	Sandy Dry Value	0.574	0.974	X = 4
2.	V dry + C dry + V wet + C wet	0.327	0.912	X = 10
3.	(V dry + C dry)*(V wet + C wet)	0.285	0.894	X = 25
4.	Godlove (1951) and Melville & Atkinson (1985) index: Dry colour relative to reference colour *(hereafter referred to as the M&A Index)*	0.386	0.869	X = 6
5.	V + C (dry)	0.377	0.856	X = 5
6.	Value (Dry - Wet)	0.198	0.852	X = 2
7.	Value (Dry + Wet)	0.376	0.828	X = 6
8.	V + C (wet)	0.235	0.826	X = 4.5
9.	Clayey Wet Value	0.396	0.826	X = 3
10.	Wet Chroma	0.146	0.815	X = 1.5
11.	V dry * V wet	0.345	0.805	X = 10
12.	Sandy Wet Value	0.207	0.742	X = 3
13.	Dry Value	0.379	0.729	X = 5
14.	Wet Value	0.217	0.713	X = 3
15.	Clayey Dry Value	0.497	0.703	X = 3

Table 8.4. Assumptions regarding Munsell colour indices and SOC.

	Munsell colour indices	r^2
1.	When the dry Value in sandy soils (clay < 10%) is 4 or more, SOC content will be 1.75% and less.	0.97
2.	When the sum of dry and wet Value and Chroma values is 9 or more, SOC content will be 4.79% and less.	0.91
3.	When the colour index '(V dry + C dry)*(V wet + C wet)' is 25 or more, SOC content will be 4.7% and less.	0.89
4.	When the colour index of Godlove (1951) and the M&A Index is 6 or more, SOC content will be 8.26% or less.	0.87
5.	When the sum of dry Value and Chroma values is 5 or more, SOC content will be 5.7% or less.	0.86
6.	When the difference between dry and wet Value is 2 or more, SOC content will be 6.87% or less. That is to say, the larger the difference between dry and wet value, the lower the SOC content will be.	0.85
7.	When the sum of dry and wet Value is 6 or more, SOC content will be 4.81% or less.	0.83
8.	When the sum of wet Value and Chroma values is 4.5 or more, SOC content will be 2.95% or less.	0.83
9.	When the wet Value in clayey soils (clay > 10%) is 3 or more, SOC content will be 1.17% or less.	0.83
10.	When the wet Chroma value is 1.5 or more, SOC content will be 3.17% or less.	0.82
11.	When the multiplication of dry and wet Value is 10 or more, SOC content will be 4.48% or less.	0.81
12.	When the wet Value of sandy soils (clay < 10%) is 3 or more, SOC content will be 0.94% or less.	0.74
13.	When dry Value is 3.5 or more, SOC content will be 3.79% or less	0.73
14.	When the wet Value is 3 or more, SOC content will be 2.71% or less.	0.71
15.	When the dry Value in clayey soils (clay > 10%) is 3 or more, SOC content will be 2.97% or less.	0.70

Interesting inferences can be made from the above (Table 8.4):

- Statement 6: The larger the difference between dry and wet value, the lower the SOC content will be.
- Statement 1 and 15: Dry Value in sandy soils has a correlation of 0.974 but dry Value in clayey soils only 0.703. A specific Dry value in sandy soils will give notably lower SOC content, than the same dry value in clayey soils. As an example a dry value of 4 or more will have a SOC content of 1.75% or less in a sandy soil and 3.96% or less in a clayey soil. This means that for the same colour you will have less SOC in a sandy soil than in a clayey soil; or a lighter colour in a clay soil may have the same SOC content than a darker colour in sand.
- Statement 9, 12, and 14: Similarly wet value gives good correlations in sandy and clayey soil separately (0.742 and 0.826), but in a combination of soil types, because the correlation is lower (0.713). If wet Value equals 3 or more for all three statements, SOC content would be 1.17% or less in clayey soils; 0.94% or less in sandy soils; and 2.71% or less in a combination of soils. Ergo similar colour may indicate a higher SOC value in clay than in sand.

- Statements 1, 12, 14, and 15: The difference in SOC content for the same colour value in sandy and clayey soil was much higher when using the Dry Munsell value as opposed to the wet Munsell value. However, the correlation varied as well.

8.3 Topsoil colour as indicator of wetland zone boundaries

8.3.1 Significant colour differences down a topographical gradient

The following indices with high correlations from 8.2 were used to see whether topsoil colour can differentiate between the various zones on the topographical gradient:

- Dry colour value
- Godlove (1951) and the M&A Index
- Wet Value
- DCV-WCV
- DCV+WCV
- V dry * V wet
- V + C (dry)
- V + C (wet)
- V dry + C dry
- (V dry + C dry)*(V wet + C wet)

The results are indicated per wetland type. Only the indices where there was at least one significant difference between the wetland zones of one of the types are indicated in Table 8.5 and Figure 8.4:

Table 8.5. p-values indicating statistical differences between zones for each wetland type.

Munsell colour index	Type	ANOVA (p-value)
Dry colour value	Interdunal Depressions	0.102
	Muzi Swamp	0.078
	Tembe Park Perched Pans	0.226
	Moist Grasslands	0.001
Godlove (1951) and the M&A Index	Interdunal Depressions	0.069
	Muzi Swamp	0.228
	Tembe Park Perched Pans	0.225
	Moist Grasslands	0.003
Value (Dry - Wet)	Interdunal Depressions	0.019
	Muzi Swamp	0.876
	Tembe Park Perched Pans	0.633
	Moist Grasslands	0.002
Value (Dry + Wet)	Interdunal Depressions	0.096
	Muzi Swamp	0.006
	Tembe Park Perched Pans	0.145
	Moist Grasslands	0.002

Significant differences were found in:

1. Dry colour value:

- in the Moist Grasslands, between zones
    - 1 & 3,
    - 1& 4, and
    - 2 & 4.

2. Godlove (1951) and the M&A Index - Dry colour relative to reference colour index:

- in the Moist Grasslands, between zones
    - 1 & 4, and
    - 2 & 4

3. Value (Dry - Wet):

- in the Interdunal Depressions, between zones 1 & 4
- in the Moist Grasslands, between zones
    - 1 & 4,
    - 3 & 4, and
    - 2 &4

4. Value (Dry + Wet):

- in the Muzi Swamp, between zones
    - 1 & 4,
    - 2 & 4, and
    - 3 & 4
- in the Moist Grasslands, between zones
    - 1 & 4,
    - 1 & 3, and
    - 2 &4

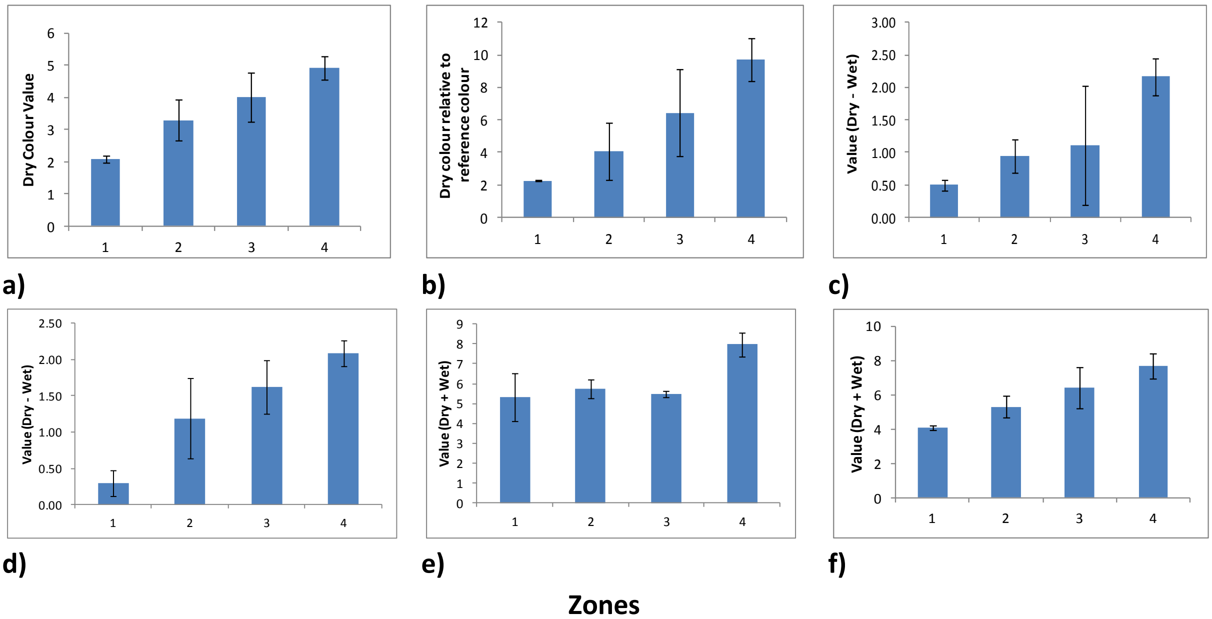

Figure 8.4. The various Munsell colour indices which illustrate significant differences between zones in the various wetland systems, where: a) the Moist Grasslands, b) the Moist Grasslands, c) the Interdunal Depressions, d) the Moist Grasslands, e) the Muzi Swamp, and f) the Moist Grasslands.

Only four of the ten tested colour indices showed significant differences between the various wetness zones in a wetland. There was therefore only a limited number of colour indices that could indicate changes in the topsoil from the terrestrial zone outside of a wetland to the saturated zone within a wetland. None of these indices could therefore be consistently applied for different wetland systems, and they were often not even applicable to all wetland systems. The Moist Grasslands seemed to show colour changes in the topsoil in a consistent manner, as there were significant differences between zones for all four colour indices, while no colour index showed any significant differences between zones in the clayey Tembe Park Perched Pans. For the Interdunal Depressions only the difference between dry and wet colour was significant, and for the Muzi Swamp only the sum of dry and wet colour was significant.

The overall consistent difference between the topsoil colours was found between zones 1 and 2 (i.e. inside the wetland) and zone 4 (outside the wetland). The implication of this was that, in terms of soil colour, a third zone of colour change does not exist. Once you start moving out of the wetland the soil colour would only have changed significantly enough to be able to quantify a change once you are in the terrestrial area. This led to the investigation of the potential to differentiate wetland from non-wetland areas based on predictably minimal turning points in the following section.

8.3.2 Differentiating wetland areas based on predictably minimal turning points

The points on the x-axis where SOC content is a minimum (Table 8.3) – i.e. the threshold values of the graphs in Figure 8.3 – were hypothesised to be the boundary of the wetland. A correlation between whether a site was defined as a wetland or not, and the results of a selection of the colour indices for topsoil were obtained. The boundaries of the wetlands were defined through a combination of field observations, visible hydrology, a literature review and personal communication with local inhabitants; as well as the soil form (DWA 2005) (Chapter 5) and indicator wetland species (Chapter 7).

Table 8.6 indicates whether the threshold values of the graphs in Figure 8.3 and Table 8.3 correlated with what were defined as wetland and non-wetland sites. In Table 8.7 these results are expressed as a percentage correlation (i.e. at how many sites per system did the colour and the wetland delineation agree correctly).

From these results it is clear that colour is approximately 70% - 100% effective as an indicator for wetland boundaries. The variation in effectiveness is dependent on wetland type, and the index used. Table 8.7 illustrates that the Muzi Swamp sites are most predictably indicated by colour (93% effective). Three of the indices tested (“DCV+WCV”, “V + C (dry)”, and “V dry + C dry + V wet + C wet”) functioned perfectly to indicate wetland boundaries in the Muzi Swamp. The Moist Grasslands has the worst results for the indication of wetland boundaries.

Of all indices “V + C (dry)” was the best indication for wetland boundaries among all indices (87% effective). However, it was also one of the worst indicator indices in the PL Type. The M&A index is a close second (85% effective), and is also more equally contributed to by the various wetland types. The large fluctuation of effectiveness of the indices within the different wetland types may indicate that an index may have different threshold values depending on the wetland type in question. This would have to be determined and tested using a much larger dataset. For this study the preferred indices for the indication of wetland boundaries within each wetland type are indicated in Table 8.8.

Table 8.6. Agreement between the colour indices' values for topsoil and whether a site was defined as a wetland or not.

Profile	Delineation	Dry Value	M&A index	Wet Value	DCV-WCV	DCV+WCV	V dry * V wet	V + C (dry)	V + C (wet)	V dry + C dry + V wet + C wet	(V dry + C dry)*(V wet + C wet)
MS 1-01	Wetland	X	X	√	√	√	√	√	√	√	√
MS 1-02	Wetland	√	√	√	√	√	√	√	√	√	√
MS 1-03	Wetland	√	√	√	√	√	√	√	√	√	√
MS 1-04	Non-wetland	√	√	√	X	√	X	√	X	√	X
MS 4-01	Wetland	√	√	√	√	√	√	√	√	√	√
MS 4-02	Wetland	√	√	√	√	√	√	√	√	√	√
MS 4-04	Wetland	√	√	√	√	√	√	√	√	√	√
MS 4-05	Wetland	√	√	X	√	√	√	√	√	√	√
MS 6-01	Wetland	√	√	√	√	√	√	√	√	√	√
MS 6-02	Wetland	√	√	√	√	√	√	√	√	√	√
MS 6-03	Wetland	√	√	√	√	√	√	√	√	√	√
MS 6-04	Non-wetland	√	√	√	√	√	√	√	X	√	X
PP 1-01	Wetland	X	X	√	√	X	X	√	√	√	√
PP 1-02	Wetland	X	X	√	√	X	√	√	√	√	√
PP 1-03	Non-wetland	√	√	X	√	√	√	√	X	√	X
PP 2-01	Wetland	X	√	√	X	X	√	√	√	√	√
PP 2-02	Wetland	X	√	√	√	√	√	√	√	√	√
PP 2-03	Non-wetland	√	√	√	X	√	√	√	√	√	√
PP 3-01	Wetland	X	√	√	√	√	√	√	√	X	√
PP 3-02	Wetland	X	√	√	√	√	√	√	√	√	√
PP 3-03	Wetland	X	√	X	√	X	X	√	X	X	√
PL 3-01	Wetland	√	√	√	√	√	√	√	√	√	√
PL 3-02	Wetland	√	√	√	√	√	√	√	√	√	√
PL 3-03	Wetland	√	√	√	√	√	√	√	√	√	√

PL 3-04	Non-wetland	√	√	X	√	√	√	X	X	√	X
PL 4-01	Wetland	√	√	√	√	√	√	√	√	√	√
PL 4-02	Wetland	X	X	√	X	X	√	X	√	√	√
PL 4-03	Non-wetland	X	√	X	X	X	X	X	X	X	X
PL 4-04	Non-wetland	√	√	X	X	√	X	X	X	X	X
PL 5-01	Wetland	√	√	√	√	√	√	√	√	√	√
PL 5-02	Wetland	X	X	√	X	√	√	√	√	√	√
PL 5-03	Non-wetland	√	√	√	√	√	√	√	√	√	√
PL 6-01	Wetland	√	√	√	√	√	√	√	√	√	√
PL 6-02	Wetland	X	X	X	X	X	X	X	X	X	X
PL 6-03	Non-wetland	√	√	√	√	√	√	√	X	√	√
IDD 2-01	Wetland	√	√	√	√	√	√	√	√	√	√
IDD 2-02	Wetland	√	√	√	√	√	√	√	√	√	√
IDD 2-03	Wetland	√	√	√	√	√	√	√	√	√	√
IDD 2-04	Non-wetland	√	√	√	√	√	√	√	√	√	√
IDD 3-01	Wetland	√	√	√	√	√	√	√	√	√	√
IDD 3-02	Wetland	√	√	√	√	√	√	√	√	√	√
IDD 3-03	Wetland	X	X	X	√	X	X	√	X	X	X
IDD 3-04	Non-wetland	√	√	√	X	√	√	√	√	√	√
IDD 5-01	Wetland	√	√	√	√	√	√	√	√	√	√
IDD 5-02	Wetland	√	√	√	√	√	√	X	√	√	√
IDD 5-03	Non-wetland	√	√	X	√	√	X	√	X	X	X
IDD 5-04	Non-wetland	√	√	X	√	√	X	√	X	X	X

Table 8.7. A percentage correlation of the sites where the colour indices and the wetland delineation agreed correctly. The threshold values are indicated in italicised brackets. MS = Muzi Swamp; PP = Tembe Park Perched Pans; PL = Moist Grasslands; IDD = Interdunal Depressions.

	MS (n = 12)	PP (n = 9)	PL (n = 14)	IDD (n = 12)	n = 47
Dry Value (*Sandy soil = 4; In general = 5)*	92%	22%	71%	92%	**72%**
M&A index *(6)*	92%	78%	79%	92%	**85%**
Wet Value *(3)*	92%	78%	71%	75%	**79%**
DCV-WCV *(2)*	92%	78%	64%	92%	**81%**
DCV+WCV *(6)*	100%	56%	79%	92%	**83%**
V dry * V wet *(10)*	92%	78%	79%	75%	**81%**
V + C (dry) *(5)*	100%	100%	64%	92%	**87%**
V + C (wet) *(4.5)*	83%	78%	64%	75%	**74%**
V dry + C dry + V wet + C wet *(10)*	100%	78%	79%	75%	**83%**
(V dry + C dry)*(V wet + C wet) *(25)*	83%	89%	71%	75%	**79%**
Average per wetland type	**93%**	**74%**	**72%**	**84%**	**80%**

Table 8.8. Preferred indices for the indication of wetland boundaries within each wetland type. MS = Muzi Swamp; PP = Tembe Park Perched Pans; PL = Moist Grasslands; IDD = Interdunal Depressions.

Preferred indices	MS	PP	PL	IDD
When the dry Value in sandy soils (clay < 10%) is 4 or more, SOC content will be 1.75% and less. AND When the dry Value in clayey soils (clay > 10%) is 3 or more, SOC content will be 2.97% or less.				√
When the colour index of the M&A Index: Dry colour relative to reference colour is 6 or more, SOC content will be 8.26% or less.			√	√
When the difference between dry and wet Value is 2 or more, SOC content will be 6.87% or less.				√
When the sum of dry and wet Value is 6 or more, SOC content will be 4.81% or less.	√		√	√
When the multiplication of dry and wet Value is 10 or more, SOC content will be 4.48% or less.			√	
When the sum of dry Value and Chroma values is 5 or more, SOC content will be 5.7% or less.	√	√		√
When the sum of dry and wet Value and Chroma values is 9 or more, SOC content will be 4.79% and less.	√		√	

8.4 Conclusion

According to Shulze et al. (1993), quantitative relationships between soil colour and organic carbon content are only poorly understood. Literature shows that a relationship between SOC and soil colour do exist, although it is often a poor relationship, and is influenced by other characteristics such as soil texture and land-use. Many studies claim to have established a correlation (Wills &

Burras 2007; Konen et al. 2003); however, few of these correlations are high, indicating the absence of a direct relationship (Lindbo et al. 1998, Ibarra et al. 1995, Franzmeier 1988, Renger et al. 1987, Steinhardt & Franzmeier 1979, Burras et al. undated). One study states that the colour of soils is not a sufficient parameter to determine SOC content (Senjobi et al. 2013).

The findings from this study confirm the results of the studies in the literature review to a large extent. Soils with dark colours can indicate either high or low SOC content. Soil with 10YR2/1 colour may have SOC content of anything from 2% to 14.5%, and similarly soil with colour 2.5Y2.5/1 may have between 2.4% and 23% SOC content. Lighter soil colours will conversely indicate low SOC content, at certain values.

The combinations of Munsell soil colour components and indices used in the study were obtained from Melville & Atkinson (1985), Evans & Franzmeier (1988), Mokma & Cremeens (1991), and Van Huyssteen et al. (1997), with resulting correlation values from anything between $r^2 = 0.004$ and $r^2 = 0.386$. Indices incorporating Munsell Value appeared to be good predictors of SOC contents. Chroma also gave good results, but Hue was found to lower correlation results. The less complicated indices also gave better results.

Many previous studies emphasise that colour can only be used to estimate SOC content when applied in the same climatic region, within the same land-use type, and within the same textural class. The data used in this study were from the same climatic region and within the same land-use type. Dividing the data into substrate types improved the previous correlation range of $r^2 = 0.004$ - 0.386, to $r^2 = 0.386$ - 0.574. These values were not much higher than reported by Steinhardt & Franzmeier (1979) and Franzmeier (1988).

Clay soils of the same colour appear to have a higher organic matter content. Conversely, coarser textures of the same colour designation have a lower organic matter content (as found by Franzmeier (1988) and Steinhardt & Franzmeier (1979) as well). This is explained by the higher amount of SOC needed to colour the larger surface area of the smaller clay particles in comparison to large sand particles.

Soil colour is a function of more than just SOC content and there may be a variety of factors which can modify the colour of a soil. Consequently the relationship between colour and SOC in this study was not a linear one, but tended to present as a scatter of values, or relational envelopes. Such scatters cannot be described by linear relationships, and therefore the only meaningful feature of these relational envelopes may be a boundary line. The shape of this describes a biotic response to an abiotic parameter and shows that potentially maximal SOC contents will occur at values of low index results, and predictably minimal SOC contents will occur at values of low or high index results. Axiomatically, this showed that although minimal SOC content can be predicted for certain colour indices, maximal SOC content cannot be predicted. Using the regression equations, threshold values were determined and a number of assumptions made based on these results. The assumption "When the sum of dry and wet Value and Chroma values is 9 or more, SOC content will be 4.79% and less" were the best correlated ($r^2 = 0.9124$).

The hypothesis that topsoil colour down a topographical gradient might be used as an indicator for the different wetland zone boundaries were shown to be true in some instances, but proved overall to be variable and unreliable. However, the hypothesis that the threshold values from the segmented quantile regression analysis can differentiate between wetland and non-wetland sites proved to be 70 – 100% effective. This implies that soil colour can indeed be used to indicate wetland boundaries. However, it would seem as if there is much variation between the effectiveness of the various indices within the various wetland types (with the Muzi Swamp being the most predictable, and the Moist Grasslands the least). The implication of this is that threshold values would have to be developed for each wetland type separately before colour can be used as an indicator of wetland boundaries. The various indices also need to be tested extensively with a much larger dataset in order to perfect the threshold values.

Of all the indices "V + C (dry)" was the best indication for wetland boundaries (87% effective), although the M&A index is a close second (85% effective), and is also much more equally contributed to by the various wetland types. The preferred indices for the indication of wetland boundaries within each wetland type are indicated in Table 8.8.

Chapter 9
WETLAND DELINEATION ON THE MAPUTALAND COASTAL PLAIN

9.1 Introduction

It was emphasised in Chapter 5, 6, and 7 that each wetland type has a unique character, and exhibits different characteristics. It is therefore impossible to equate wetland types and make sweeping statements about their value and functioning. Often wetlands are grouped into the respective HGM types, and deductions made about their character. However, on the Maputaland Coastal Plain (MCP) the different wetland types can be grouped further based on substrate type (Chapter 6, 9, and Pretorius 2011). Where a wetland type consists of more than one dominant substrate type (i.e. the Muzi Swamp and the Interdunal Depressions) certain hydrological regimes are associated with the different substrate types. The organic substrates in the Muzi Swamp, Interdunal Depressions, and Moist Grasslands wetland types, for instance, are associated with permanent wetness, and the surrounding duplex/sandy substrates with seasonal/temporary wetness. Wetland types which share substrate types can be said to share soil and vegetation characteristics (e.g. the Moist Grasslands and Interdunal Depressions which share the sandy substrate, and the Muzi Swamp, Tembe Park Perched Pans, and Utilised Perched Pans that share the duplex soil characteristics). The different wetland types can therefore be seen as:

- Muzi Swamp (MS Type): Organic-duplex wetland
- The Tembe Park Perched Pans (PP Type): Duplex pans
- The Utilized Perched Pans (DP Type): Duplex pans
- Moist Grasslands (PL Type): Sandy wetlands (some with organic soil)
- Interdunal Depressions (IDD Type): Organic-sand wetland

Wetland characteristics, functioning, and services are very much defined by their hydrological input and regulators (Mitsch & Gosselink 2000). Since wetlands on the MCP are driven mainly by groundwater fluctuations (apart from the small Perched Pans), the understanding of the substrate composition and its associated characteristics of wetland types on the MCP, is an extremely important factor in the assessment of wetlands.

The national wetland delineation guidelines (DWAF 2005) use four indicators to delineate wetlands: the Terrain Unit-, Soil form-, Soil Wetness-, and Vegetation Indicator. The first section of this chapter discusses the use of each of these indicators, as well as the soil colour indicator, in the different wetland types, based on the data discussed in Chapters 5, 6, 7, and 8. The second section deals with the limitations and application of the delineation guideline of DWAF (2005) on the MCP.

9.2 Wetland indicators in the wetland types on the MCP

The wetland types are discussed separately at hand of each of the indicators. Where the indicators appeared to be contradictory, the final classification was taken based on what the majority of indicators suggested. Emphasis was placed on personal observations, communication with local residents, and literature to confirm classifications, especially of the contradictory sites.

9.2.1 The Muzi Swamp (MS Type)

On the MCP the Muzi Swamp represents linear valley bottom wetland systems linked to the groundwater table, characterised by organic material in the centre and duplex soil on the banks. Much of the organic substrate classifies as peat. Although the dominant water source is groundwater, the wetland system also receives lateral water input from the sides where the clay layer at approximate 300mm depth acts as an aquiclude. There is a strong calcium carbonate influence in both the duplex soil as well as in the high organic substrates. This has a marked effect on the pH of the soil which, with the high clay content, results in generally high CEC values.

The Terrain Unit Indicator

The Muzi Swamp occurs in the valley bottom topographical position. Following the classification by Ollis et al. (2013), the wetlands classify as Valley Bottom with and without a channel. The slope on the eastern bank of the system where sampling took place is gradual and long, and characterized by discrete vegetation changes. Horizons that are indicative of water movement, such as plinthic horizons and materials with signs of wetness, are very common in all positions on the slope.

Soil Form and Wetness Indicator

Refer to Table 9.1, Column 3 - 6. The Champagne soil form invariably characterises the inner zones and is probably associated with the areas of groundwater discharge. The other soil forms encountered on the slope – Westleigh, Longlands, Brandvlei , and Fernwood – are supposedly indicative of seasonal or temporary wetness (DWAF 2005), due to either signs of wetness at family level or an inherent plinthic character (which may or may not occur within the 500 mm cut-off depth for wetland delineation; Kotze et al. 1996, Soil Classification Working Group 1991). The Brandvlei soil form always occurs close to the crest of the slope – and is classified as either a non-wetland or a temporarily flooded site. Possibly this soil form will not occur in linear, valley bottom wetland systems other than the Muzi Swamp, as it requires the calcium carbonate influence to be diagnostic. The Longlands soil form occurs in the upland position once. While the plinthic character indicates lateral/vertical water movement, it is at a depth outside the 500 mm wetland delineation requirement. Therefore, just because the Brandvlei and Longlands soil forms may indicate wetland conditions, it should not be exclusively viewed as wetland soils. According to Kotze et al. (1996), this is a weakness of the soil classification system since the depth of waterlogging is quite an important factor.

The Muzi Swamp has mottling in the topsoil of most of the catena. Despite the suggestion that mottling is masked by highly organic soils (Richardson & Vepraskas 2001), mottles were encountered in many of the peat substrates. Mottles were also encountered in the two sites classified as non-wetland sites, but other indicators such as slope position, vegetation, and soil colour indicated non-wetland conditions. The mottling sequence illustrated in Kotze et al. (1996), where no mottles are in the permanent zones, many in the seasonal, few in the temporary and none in the non-wetland sites, does not work well in the Muzi Swamp. Mottling appears to be somewhat associated with specific horizons, as it was rarely found in the Orthic A horizons on the slope (possible masked by organic material), in some peat layers, and in E-horizons.

Using soil form as an indicator therefore appears to work well in the Muzi Swamp, although care should be taken when interpreting the soil forms close to the crest, which may be taken to indicate wetness when in fact it does not. Although mottles are present, it does not correlate exactly with the vegetation indicator in some sites.

Vegetation indicator

The Weighted Averaging of sites using the indicator status of plants appears to indicate wetland and non-wetland conditions fairly well (Chapter 7) in the Muzi Swamp. Those sites associated with groundwater exfiltration (high organic sites) invariably fall within the 'Wetland' class, while the seasonal and temporarily flooded sites are 'Good probability of wetland' or 'Inconclusive'. One site fell into the 'Upland' class, but was classified as temporarily wet due to the presence of abundant mottles. Overall the vegetation appears to indicate a sharp transition from the 'Wetland'- and 'Good probability of wetland' class to the 'Upland' sites. Indicator species in the Muzi Swamp are:

- Wetland: *Phragmites australis, Phyla nodiflora, Dactyloctenium aegyptium, Imperata cylindrica*
- Non-wetland: *Hyperthelia dissoluta, Eragrostis superba*

Soil colour indicator

Assuming the other indicators were interpreted correctly, the soil colour indicator had a perfect indication of wetland and non-wetland conditions in the Muzi Swamp.

Table 9.1. The white columns specify the site, soil form, and mottling indicator data for each site in the Muzi Swamp. The lightly shaded columns indicate the classification based on each indicator. The final, dark shaded column is the final classification made by taking all indicators into account. The upland sites are blocked for rapid identification when viewing the table.

Site	Initial site classification[1]	Soil Form	Site classification according to the soil form (DWA 2005)	Mottling within 500 mm	Second site classification[2]	Third site classification[3]	Soil colour indicator[4]	Delineation based on all indicators
MS 1-01	Permanent saturation	Champagne	Permanent	Few[5]	Permanent	Wetland	Wetland	Permanent
MS 1-02	Permanent saturation	Champagne	Permanent	-	Permanent	Good probability of wetland	Wetland	Permanent
MS 1-03	Seasonally flooded	Westleigh	Seasonal/Temporary	Few	Seasonal	Good probability of wetland	Wetland	Seasonal
MS 1-04	Upland	Longlands	Seasonal/Temporary	Common, below 450 mm	Temporary	Upland	Non-Wetland	Non-Wetland
MS 4-01	Permanent saturation	Champagne	Permanent	-	Permanent	Wetland	Wetland	Permanent
MS 4-02	Permanent saturation	Champagne	Permanent	Common	Permanent	Wetland	Wetland	Permanent
MS 4-04	Seasonally flooded	Westleigh	Seasonal/Temporary	Few	Seasonal	Good probability of wetland	Wetland	Seasonal
MS 4-05	Upland	Brandvlei	Seasonal/Temporary	Common	Seasonal	Upland	Wetland	Temporary
MS 6-01	Permanent saturation	Champagne	Permanent	Few	Permanent	Wetland	Wetland	Permanent
MS 6-02	Permanent saturation	Champagne	Permanent	Common	Permanent	Wetland	Wetland	Permanent
MS 6-03	Seasonally flooded	Fernwood	Seasonal/Temporary	Many	Seasonal	Inconclusive	Wetland	Seasonal
MS 6-04	Upland	Brandvlei	Seasonal/Temporary	Few	Temporary	Upland	Non-Wetland	Non-Wetland

[1] Based on visible hydrology, literature, and personal communication with locals
[2] Strictly based on soil indicators and slope position (Chapter 5)
[3] Based on vegetation WA scores (Chapter 7)
[4] Chapter 8
[5] Few: < 2%; Common: 2 – 20%; Many: >20%

9.2.2 *The Tembe Park Perched Pans (PP Type)*

The Tembe Park Perched Pans represent the clay pans occurring inside the Tembe Elephant Park (TEP) parallel to the Muzi Swamp. These pans are characterised by duplex soil. In terms of location, substrate type, and water source these pans are very similar to the perched pans outside Tembe Park (DP Type). The pans are replenished by rainwater and some lateral ground water movement, and are not linked to the groundwater table. The soil has a calcareous and duplex character, and is coarsely structured with a hard consistence within the pans, which decreases towards the outside of the pans. The substantial increase in clay in these subsoil horizons in the upper part of the pans plays an important role in the sustaining of the perched water table after rain events. Deep G horizons are commonly found, adding to the observed seasonality of the pans.

The Terrain Unit Indicator

The pans classify as depressions (Ollis et al. 2013). Although they are small and circular shaped with only a slight gradient to the surrounding crest, there are clear boundaries of vegetation change along the catena.

Soil Form and Wetness Indicator

Refer to Table 9.2, Column 3 - 6. The Tembe Park Perched Pans do not adhere to the textbook example of soil form and wetness indicators. A Katspruit soil form, according to DWAF (2005), will always be found in the permanently wet zone of a wetland (although Kotze et al. (1996) specify that it is a seasonal soil form in humid areas such as the MCP). The other two soil forms encountered – Sterkspruit and Valsrivier – are both not listed in the DWAF (2005) guidelines, and are therefore not regarded as wetland soil forms. It is clear that in the case of the Tembe Park Perched Pans these guidelines are not applicable. Although the Katspruit is always found towards the centre of the pans, these pans are not permanently saturated, based on literature (Matthews et al. 2001) and visual observations. Signs of wetness in terms of mottling are difficult to interpret in these pans. The Valsrivier soil form is found on the crest around the pan, is not regarded as a wetland soil, yet have many redoximorphic features indicating seasonal wetness. However, the vegetation indicator also supports the non-wetland classification, therefore the final classification is given as temporarily wet for that specific transect. In another transect the Sterkspruit soil form, supposedly non-wetland, occurs across the whole catena. Mottles were only associated with the Prismacutanic horizon (Addendum A) in this soil form. While no redoximorphic features were found within 500 mm in the profiles inside the pan (yet they were present within 500 mm on the top of the crest), it is known from personal and other observations that the pan is seasonally wet in the first two zones. Additionally, the vegetation clearly shows a trend from wetland vegetation to upland vegetation. Why redoximorphic features do not form in the top soil (A-Horizon) of the Sterkspruit soil form inside the pan, yet formed to some extent on the crest where the vegetation indicator shows non-wetland conditions, is not clear.

Caution is therefore advised when using soil form and wetness as an indicator for wetland boundaries in clay-dominated wetland types.

Table 9.2. The white columns specify the site, soil form, and mottling indicator data for each site in the Tembe Park Perched Pans. The lightly shaded columns indicate the classification based on each indicator. The final, dark shaded column is the final classification made by taking all indicators into account. The upland sites are blocked for rapid identification when viewing the table.

Site	Initial site classification[1]	Soil Form	Site classification according to the soil form (DWA 2005)	Mottling within 500 mm	Second site classification[2]	Third site classification[3]	Soil colour indicator[4]	Delineation based on all indicators
PP 1-01	Seasonally flooded	N/A	N/A	N/A	Seasonal	Wetland	Wetland	Seasonal
PP 1-02	Seasonally flooded	Katspruit	Permanent	Few	Permanent	Wetland	Wetland	Seasonal
PP 1-03	Periodically flooded	Sterkspruit	Terrestrial	Below 500 mm	Terrestrial	Upland	Non-Wetland	Non-Wetland
PP 2-01	Seasonally flooded	Sterkspruit	Terrestrial	Below 500 mm	Terrestrial	Wetland	Wetland	Seasonal
PP 2-02	Seasonally flooded	Sterkspruit	Terrestrial	Below 500 mm	Terrestrial	Inconclusive	Wetland	Seasonal
PP 2-03	Periodically flooded	Sterkspruit	Terrestrial	Few lime mottles	Terrestrial	Upland	Non-Wetland	Non-Wetland
PP 3-01	Seasonally flooded	Katspruit	Permanent	Few	Permanent	Wetland	Wetland	Seasonal
PP 3-02	Seasonally flooded	Katspruit	Permanent	Few	Permanent	Upland	Wetland	Seasonal
PP 3-03	Periodically flooded	Valsrivier	Terrestrial	Common	Seasonal	Upland	Non-Wetland	Temporary

[1] Based on visible hydrology, literature, and personal communication with locals
[2] Strictly based on soil indicators and slope position (Chapter 5)
[3] Based on vegetation WA scores (Chapter 7)
[4] Chapter 8

Vegetation indicator

The vegetation indicator in this wetland type was strongly relied on due to the clear transitions from wetland vegetation (*Lemna gibba, Ludwigia sp., Cyperus fastigiatus, Echinochloa colona*) to Upland vegetation (*Justicia flava, Panicum maximum, Digitaria eriantha, Euclea undulata*), as well as the contradicting soil form and wetness indicators. Only in the one transect did the vegetation indicate the site to be an upland area while the site was classified as temporarily wet due to the prominent, red, oxidized iron oxide mottling present in the A-horizon. Here there is also a sharp distinction between sites falling into the 'Wetland' class and the 'Upland' class (refer to Figure 7.7), based on the WA results (Chapter 7).

Indicator wetland species in the Tembe Park Perched Pans are: *Eragrostis rotifer, Ludwigia species, Spirostachys africana, Panicum maximum, Acacia karroo.*

Soil colour indicator

The soil colour indicator correlated perfectly with the vegetation indicator. Since the vegetation indicator was mostly regarded as a good indication of wetland and non-wetland vegetation, the colour indicator can also be regarded as a strong indicator.

9.2.3 The Utilised Perched Pans (DP Type)

These pans are examples of duplex soil. While the Tembe Park Perched Pans (PP Type) occur within the Tembe Elephant Park, the Utilized Perched Pans (DP Type) occur somewhat more to the south outside the Park (still west of the MS Type). The DP Type is similar to the PP Type in terms of location, substrate type, and water supply, but is dissimilar on the basis of existing anthropological influences (not being conserved it is exposed to fire, grazing, and the clearing of the natural vegetation), longer periods of saturation, and a more pronounced influence of calcrete (these pans are possibly in closer contact to the underlying Uloa/Umkwelane Formation layer) (Chapter 4). The pans in the DP Type also vary in size. The transects in each of the pans of the DP Type consisted of a different number of zones (3 to 5 zones each). In each transect the last zone was sampled on top of the crest surrounding the pan. However, once data were collected it was found that the last zone on the crest probably does not qualify as a terrestrial (upland) site after all.

The Terrain Unit Indicator

The pans classify as depressions (Ollis et al. 2013). Although they are small and circular shaped with only a slight gradient to the surrounding crest, there are clear boundaries of vegetation change along the catena.

Table 9.3. The white columns specify the site, soil form, and mottling indicator data for each site in the Utilized Perched Pans. The lightly shaded columns indicate the classification based on each indicator. The final, dark shaded column is the final classification made by taking all indicators into account. No upland sites are classified in the DP Type.

Site	Initial site classification[1]	Soil Form	Site classification according to the soil form (DWA 2005)	Mottling within 500 mm	Second site classification[2]	Third site classification[3]	Soil colour indicator[4]	Delineation based on all indicators
DP 1-01	Seasonally flooded	Westleigh	Seasonal or Temporary	Many, from 300mm	Seasonal	Wetland	N/A	Seasonal
DP 1-02	Seasonally flooded	Longlands	Seasonal or Temporary	Few	Seasonal	Wetland	N/A	Seasonal
DP 1-03	Seasonally flooded	Kinkelbos	Seasonal or Temporary	Few	Seasonal	Inconclusive	N/A	Seasonal
DP 1-04	Periodically flooded	Longlands	Seasonal or Temporary	Few	Temporary	Inconclusive	N/A	Temporary
DP 2-01	Seasonally flooded	Katspruit	Permanent	None	Permanent	Wetland	N/A	Seasonal
DP 2-02	Seasonally flooded	Katspruit	Permanent	Many	Seasonal	Wetland	N/A	Seasonal
DP 2-03	Seasonally flooded	Kroonstad	Seasonal or Temporary	Few	Seasonal	Wetland	N/A	Seasonal
DP 2-04	Seasonally flooded	Montagu	Seasonal or Temporary	Many	Seasonal	Good probability of wetland	N/A	Seasonal
DP 2-05	Periodically flooded	Sepane	Seasonal or Temporary	Few	Temporary	Inconclusive	N/A	Temporary
DP 3-01	Seasonally flooded	Katspruit	Permanent	Few	Seasonal	Wetland	N/A	Seasonal
DP 3-02	Seasonally flooded	Katspruit	Permanent	Few	Seasonal	Wetland	N/A	Seasonal
DP 3-03	Periodically flooded	Molopo	Seasonal or Temporary	None	Temporary	Inconclusive	N/A	Temporary

[1] Based on visible hydrology, literature, and personal communication with locals
[2] Strictly based on soil indicators and slope position (Chapter 5)
[3] Based on vegetation WA scores (Chapter 7)
[4] Chapter 8

Soil Form and Wetness Indicator

Refer to Table 9.3, Columns 3 - 6. A wide variety of soil forms occurs in the Utilised Perched Pans. Except for the Katspruit soil form (which occurrence in the Perched Pans was discussed in Section 9.2.2), all soil forms are indicative of seasonal/temporary wetness. Signs of wetness are present in all of two soil forms – the Molopo and the Katspruit. Last mentioned soil forms were still classified as seasonal/temporarily wet as a result of the other indicators. All the temporarily wet sites had little or no mottling. Although this complies with the textbook example of Kotze et al. (1996), many other seasonally wet zones also had little or no mottling present. Unfortunately the presumed crest position of the pans did not turn out to be non-wetland sites. Therefore no terrestrial (upland) sites were sampled to which the soil form and wetness indicator could be compared.

Therefore using soil form and wetness as indicators appear to work well in the Utilised Perched Pans. However, since the upland sites seem to be under-sampled, it is unknown what completely terrestrial soil looks like.

Vegetation indicator

Similar to the soil indicator, the vegetation did not indicate any non-wetland sites either. There was, however, a gradient from 'Wetland' sites to sites classified as 'Inconclusive' (sites which could, or could not be wetland sites (refer to Section 7.2.3)). This confirms that non-wetland sites for the DP Type were unintentionally under-sampled.

Indicator wetland species in the Utilised Perched Pans are: *Echinochloa colona, Cynodon dactylon, Justicia flava*

Soil colour indicator

There were no data for the soil colour indicator available for the DP Type.

9.2.4 Moist Grasslands (PL Type)

The Moist Grasslands represent sandy, flat, periodically flooded, grassland areas, with localised permanently wet depressions. Flooding occurs during high rainfall seasons, or following intense rain events. The groundwater table is recharged to such an extent as to induce open water or saturated soil conditions in the slight depressions occurring in this flat landscape. These slight depressions are often surrounded by low ridges. The Moist Grassland systems are broad and expansive, and are similar (although somewhat drier) to the hygrophilous grasslands described elsewhere on the MCP by Siebert et al. (2011), Matthews (1999), and Lubbe (1997). In terms of wetland delineation it hardly makes sense to delineate the pockets of wetlands between these Lala Palm dominated ridges. Rather the whole area should be regarded as an area with a high water table, with areas where potential flooding is highly likely.

Table 9.4. The white columns specify the site, soil form, and mottling indicator data for each site in Moist Grasslands. The lightly shaded columns indicate the classification based on each indicator. The final, dark shaded column is the final classification made by taking all indicators into account. The upland sites are blocked for rapid identification when viewing the table.

Site	Initial site classification[1]	Soil Form	Site classification according to the soil form (DWA 2005)	Mottling within 500 mm	Second site classification[2]	Third site classification[3]	Soil colour indicator[4]	Delineation based on all indicators
PL 3-01	Seasonally flooded	Fernwood	Seasonal or Temporary	Common	Seasonal	Inconclusive	Wetland	Seasonal
PL 3-02	Periodically flooded	Longlands	Seasonal or Temporary	Few	Temporary	Good probability of wetland	Wetland	Temporary
PL 3-03	Periodically flooded	Fernwood	Seasonal or Temporary	Few	Temporary	Good probability of wetland	Wetland	Temporary
PL 3-04	Upland	Fernwood	Seasonal or Temporary	Few, below 100 mm	Temporary	Good probability of Upland	Non-Wetland	Non-Wetland
PL 4-01	Permanent saturation	Champagne	Permanent	-	Permanent	Wetland	Wetland	Permanent
PL 4-02	Periodically flooded	Fernwood	Seasonal or Temporary	Few, below 350 mm	Temporary	Good probability of wetland	Wetland	Temporary
PL 4-03	Periodically flooded	Fernwood	Seasonal or Temporary	-	Terrestrial	Good probability of Upland	Wetland	Non-Wetland
PL 4-04	Upland	Fernwood	Seasonal or Temporary	-	Terrestrial	Inconclusive	Wetland	Non-Wetland
PL 5-01	Periodically flooded	Fernwood	Seasonal or Temporary	Few, below 200 mm	Temporary	Inconclusive	Wetland	Temporary
PL 5-02	Periodically flooded	Fernwood	Seasonal or Temporary	-	Temporary	Good probability of wetland	Wetland	Temporary
PL 5-03	Periodically flooded	Fernwood	Seasonal or Temporary	Few, below 100 mm	Temporary	Upland	Non-Wetland	Upland

[1] Based on visible hydrology, literature, and personal communication with locals
[2] Strictly based on soil indicators and slope position (Chapter 5)
[3] Based on vegetation WA scores (Chapter 7)
[4] Chapter 8

PL 6-01	Periodically flooded	Fernwood	Seasonal or Temporary	-	Terrestrial	Good probability of wetland	Wetland	Temporary
PL 6-02	Periodically flooded	Fernwood	Seasonal or Temporary	-	Terrestrial	Good probability of wetland	Non-Wetland	Temporary
PL 6-03	Periodically flooded	Fernwood	Seasonal or Temporary	-	Terrestrial	Upland	Non-Wetland	Upland

The Terrain Unit Indicator

The Moist Grasslands are classified as ‘flats’ by Ollis et al. (2013), although Grundling (2014) classified them as depressions. The gradient from the slight depressions to the surrounding Lala Palm ‘ridges’ is long and very gradual. Vegetation and soil changes along this gradient are slight, and result in vague boundaries.

Soil Form and Wetness Indicator

Refer to Table 9.4, Columns 3 - 6. The Moist Grasslands are almost invariably characterised by the Fernwood soil form. This soil form has two families which are distinguished based on the colour of the A-horizon (which is ascribed to wetness levels). Fernwood soil does not necessarily indicate wetland conditions. The Champagne soil form indicates a high build-up of organic matter and – carbon, which will only take place under permanent saturation.

The presence and absence of mottling in the PL Type is variable, and it is difficult to establish a specific pattern. Most profiles in the PL Type have a few fine mottles in the subsoil. Mottling appears not to be restricted to a position on the gradual slope, which may be because the whole flat system is a recharge area characterised by occasional flooding. One of the transects exhibited no mottling at all. The current hypothesis is that mottling appears quickly after rain events, but also disappears quickly again (Chapter 4). It is therefore not a reliable indicator in this wetland type.

Vegetation indicator

The vegetation indicates the non-wetland sites relatively well, although the gradient from the ‘Wetland’ class to the ‘Upland’ class (Figure 7.7) is much more diffuse than in the other wetland types. One non-wetland site classified as ‘Inconclusive’. In this wetland type a site classifying as ‘Good probability of upland’ can be regarded as a non-wetland site. Sites classifying as ‘Inconclusive’ should be considered with other indicators also. This wetland type is a cryptic wetland type (Day et al. 2010), which makes delineation extremely difficult. Vegetation appears to be a good indicator in this wetland type, but when vegetation classifies as ‘Inconclusive’, care should be taken. All possible indicators should be taken into account. *Helichrysum kraussii,* when present, appears to be a very good indicator of non-wetland conditions.

Soil colour indicator

The soil colour did not indicate wetland and non-wetland sites perfectly. In two cases the soil colour indicated wetland sites (classified as such based on agreement of both the soil and vegetation indicators) to be upland sites. It could be that with more data in similar sites, the threshold values which currently determine whether a site is a wetland or not can be refined specifically for this wetland type (Chapter 8).

9.2.5 Interdunal Depressions (IDD Type)

The Interdunal Depression system represents small, highly organic- or peat bodies enclosed in deep depressions within surrounding dune fields. These systems usually occur in the low-lying dune areas approaching the eastern sea-board in many areas on the MCP. These depressions share characteristics with the Muzi Swamp and the Moist Grasslands, in terms of the peat substrate and the sandy soil, respectively. The peat is typically not very deep, and in some of these depressions almost not deep enough to classify as a peat substrate. The sand on the dune surrounding the peat body is typically not reworked very well and little pedogenesis has taken place.

The Terrain Unit Indicator

The Interdunal Depressions is classified as a 'Depression' by (Ollis et al. 2013). The peat bodies are usually enclosed by dunes with moderate to very steep gradients, and therefore will never be saturated up to the crest, unlike some of the other wetland types. Typically the first two zones are characterised by a permanently saturated high organic matter substrate; the third zone is a transition zone between the wetland and the upland dune substrate; and the fourth zone is on the dune crest.

Soil Form and Wetness Indicator

Refer to Table 9.5, Columns 3 - 6. Similar to the Muzi Swamp, the Champagne soil form is present in most of the inner two zones of the depressions, and is directly associated with the presence of the groundwater table. The highly organic Champagne soil form is directly followed with a sandy Namib or Fernwood soil form. The Namib is supposedly a non-wetland soil form, but based on observations over the years as well as the vegetation indicator it could clearly sometimes classify as a soil that gets flooded occasionally. Whether a profile was classified as a Fernwood or a Namib was mostly based on the amount of reworking of the sands that took place to form a discrete E-Horizon or not. This additional reworking to form a Fernwood soil form could possibly be due to higher exposure to fluctuating water levels. The possibility therefore exists that all the Fernwoods in the Moist Grasslands were Namib soil forms which changed to Fernwood soil forms following prolonged flooding and drying.

Very few redoximorphic features were observed. As with the other wetland types the mottling is not reliable, as the only mottles were found in the Champagne and on the dune crests (mostly deeper than 500 mm).

Using soil form as an indicator therefore appears to work well in the Interdunal Depressions, since the change from permanent wet substrates to non-wetland conditions is sharp, with only a small seasonal zone present.

Vegetation indicator

The vegetation indicator correlated perfectly with the classification of wetland and non-wetland sites. There are no sites classified as 'Inconclusive' or 'Good probability of Upland', which means that the transition from wetland vegetation to completely non-wetland vegetation is quite distinct and easily discernible.

Indicator species in the Interdunal Depressions are:

- Wetland: *Rhynchospora holoschoenoides, Thelypteris interrupta, Xyris capensis*
- Non-wetland: *Digitaria eriantha, Cyperus obtusiflorus, Themeda triandra*

Soil colour indicator

The soil colour indicator did not correlate perfectly with the classification of wetland and non-wetland sites, as one occasionally flooded site was erroneously classified as non-wetland, and two upland sites were classified as ‘unclear’, which means that exactly half of the colour indices tested classified it incorrectly, and the other half classified it correctly. Whether it is a good indicator or not for that specific site, is therefore unclear.

Table 9.5. The white columns specify the site, soil form, and mottling indicator data for each site in the Interdunal Depressions. The lightly shaded columns indicate the classification based on each indicator. The final, dark shaded column is the final classification made by taking all indicators into account. The upland sites are blocked for rapid identification when viewing the table.

Site	Initial site classification based on visible hydrology, literature, and personal communication with locals	Soil Form	Site classification according to the soil form (DWA 2005)	Mottling within 500 mm	Site classification strictly based on soil indicators and slope position	Site classification based on vegetation WA scores	Soil colour indicator	Site delineation based on all indicators
IDD 2-01	Permanent saturation	Champagne	Permanent	-	Permanent	Wetland	Wetland	Permanent
IDD 2-02	Permanent saturation	Champagne	Permanent	-	Permanent	Good probability of wetland	Wetland	Permanent
IDD 2-03	Periodically flooded	Namib	Terrestrial	-	Terrestrial	Good probability of wetland	Wetland	Temporary
IDD 2-04	Upland	Namib	Terrestrial	Few, below 50 mm	Terrestrial	Upland	Non-Wetland	Non-Wetland
IDD 3-01	Permanent saturation	Champagne	Permanent	Many	Permanent	Wetland	Wetland	Permanent
IDD 3-02	Seasonally flooded	Fernwood	Seasonal or Temporary	-	Temporary	Wetland	Wetland	Seasonal
IDD 3-03	Periodically flooded	Fernwood	Seasonal or Temporary	Only below 500 mm	Temporary	Good probability of wetland	Non-Wetland	Temporary
IDD 3-04	Upland	Namib	Terrestrial	-	Terrestrial	Upland	Non-Wetland	Non-Wetland
IDD 5-01	Permanent saturation	Champagne	Permanent	-	Permanent	Good probability of wetland	Wetland	Permanent
IDD 5-02	Permanent saturation	Champagne	Permanent	-	Permanent	Wetland	Wetland	Permanent
IDD 5-03	Periodically flooded	Namib	Terrestrial	Only below 500 mm	Terrestrial	Upland	Unclear	Non-Wetland
IDD 5-04	Upland	Namib	Terrestrial	Only below 700 mm	Terrestrial	Upland	Unclear	Non-Wetland

9.3 Comments on wetland delineation in South Africa, and the MCP in particular

According to DWAF (2005) delineation on the MCP is similar to anywhere else in the country, but with refinement to the soil wetness indicator. The delineation procedure in sandy coastal areas involves:

1. "Classification of stream channels using hydrology"

- Not applicable to this study as no stream channels were investigated.

2. "Recognition of the terrain morphological unit which must be in a bottom-land site"

- This is true for most wetlands on the MCP, apart from the Moist Grassland wetland type which is classified as a 'Flat' wetland type, and is located at the highest elevation of all wetland types (Figure 4.2).

- The valley bottoms and deep depressions are associated with groundwater discharge, and therefore high organic matter.

- Since groundwater fluctuations drive the functioning of most wetlands on the MCP, the gradient of the topography surrounding the wetland plays a major role in how and where the boundary of the wetland manifests. For instance the steep slope in the Interdunal Depression (IDD Type) results in a clear cut boundary between wetland and non-wetland conditions. The gradual slope of the flat Moist Grasslands (PL Type) results in an area with diffuse wetland boundaries. This follows the argument of inundation versus saturation in Day et al. (2010), who states that "the likelihood of a cryptic wetland being inundated versus saturated during wet season conditions can be determined on the basis of setting, with inundation most likely in depressions … and in valley bottoms. Saturation rather than inundation is more likely to occur if a wetland is located on a slope. … topographic indicators can provide a useful dry season indication of wetland type, but they cannot be assumed to confirm the presence or absence of a cryptic wetland …"

- Although Grundling (2014) stated that wetland function on the MCP is not captured by the HGM classification, this criterion is valid when it comes to wetland delineation. However, it is of great importance to recognize not only the terrain unit, but also the gradient and morphology of the unit; and subsequently evaluate the effect of the combination of the substrate type and the terrain characteristics on the hydrological regime.

3. "Recognition of hydrophilic vegetation, if undisturbed"

- The Weighted Averaging method applied in this study is a refined version of what is recommended by the delineation manual (DWAF 2005). Since this WA approach has been shown to be an effective and prominent indicator on the MCP (Chapter 7), it is recommended for the evaluation of vegetation communities as wetland and non-wetland indicators. It requires similar levels of expertise as the method in the delineation manual, but has the added advantage of being quantitative. It also results in more categories which are open for interpretation. It would be of added advantage if the list of Glen (undated) is published. From there more research would be required to refine the list for different areas of the country, as is also recommended by the delineation manual.

• The vegetation indicator is most effective if evaluated per wetland type. Some wetland types are evaluated more effectively with the vegetation indicator than others. For instance, the Interdunal Depressions has sharp distinctions between vegetation WA categories which correlate perfectly with what are wetland and non-wetland sites. The Moist Grasslands on the other hand has very diffuse transitions.

• Although the delineation guideline specifies that "when using vegetation indicators for delineation, emphasis is placed on the group of species that dominate the plant community, rather than on individual indicator species", Chapter 7 has shown that when the wetland types are evaluated individually, some prominent indicator species can be used for delineation of zones as well as wetland/non-wetland sites. Without much in-depth research, this approach is however not viable as an umbrella-method for the whole country.

• According to DWAF (2005) vegetation is the primary indicator (under normal circumstances), but in practice the soil wetness indicator tends to be the most important. This is because vegetation responds relatively quickly to changes in soil moisture regime or management and may be transformed; whereas the morphological indicators in the soil are far more permanent and will hold the signs of frequent saturation for a long period of time. Although this is true, and probably also the reason why there is sometimes a discrepancy between the vegetation and soil indicator, the soil indicator has been shown not to be very reliable and predictable on the MCP. Vegetation is therefore an effective delineation measure. This will have to be tested in a wet period, however, since the current drought may result in the delineation of a reduced wetland area when using the vegetation indicator.

4. *"Recognition of specific soil criteria associated with sandy aeolian soils:*

(i) Soil properties associated with the temporary zone of wetness in riparian and wetland habitats on sandy coastal aquifers -
If the soil form is Fernwood then the profile:

➢ *Has a dark topsoil (moist Munsell values of 4 or less and chroma values of 1 or less)"*

• A topsoil depth is not defined in the delineation guideline. Here it was tested against a topsoil depth of 100 mm. The Munsell value of 4 was found to be too high to indicate the temporary zones of wetlands, as it included both wetland and non-wetland soil in this study. A Munsell value of 3 and less correlated better with wetland sites, and is substantiated by Vepraskas (2001). However, Chapter 8 supplies much more details regarding the complexity of using colour in delineation.

• The Fernwood soil form dominates the Moist Grasslands. In this wetland type soil colour has been shown not to be a perfect indicator, although it could be refined with more data. There are four equally effective colour indices for the indicator of non-wetland boundaries:

1. The sum of dry and wet Value equalling 6 or higher (or a SOC content of 4.81% or less).
2. The multiplication of dry and wet Value equalling 10 or higher (or a SOC content of 4.48% or less);

3. The sum of dry and wet Value and Chroma values equalling 9 or higher (or a SOC content of 4.79% and less);
4. The colour index of Melville & Atkinson (1985): Dry colour relative to reference colour equalling 6 or more (or a SOC content of 8.26% or less).

➢ *"Has an extremely high topsoil organic carbon content, amounts which vary but are usually more than 7% throughout the horizon"*

- The correlation between non-wetland conditions and organic carbon is variable, as detailed in Chapter 8. It appears that colour is a better indicator of wetland versus non-wetland conditions, than soil organic carbon. The only pattern that does exist is that there is always a sharp drop in organic carbon content on the boundary from wetland to non-wetland conditions. The magnitude of carbon content differs from one situation to a next, however.

➢ *"Contains accumulation of plant residues which vary from finely divided to predominantly fibrous"*

- This was not the case in any of the Fernwood soils sampled. The topsoil rather appeared as darkly coated sand grains or organic material nodules than fibrous plant residues.

➢ *"Has a low bulk density (soil material feels 'light' and foot stamping on the soil surface often results in vibrations); has a peaty character; often exhibits vertical profile cracking in the dry state; and is susceptible to ground fires"*

- The abovementioned criteria are all characteristics of peat substrates. Firstly, peat substrates cannot be classified as Fernwood soil forms, and is associated with groundwater discharge on the MCP. It is not possible for these criteria to occur in the temporary zones of a wetland. Secondly, even if these criteria were found to be applicable to soils with less organic material than peat, it would probably still be above 10% carbon and therefore be Champagne soil forms and not Fernwood soil forms. (although ground fires have not been proven to be exclusively associated with peat soil).
- No research exists on ground fires and the amount of organic carbon required in sandy soils to sustain a smouldering layer in the subsoil. Personal communication with local residents in the Moist Grasslands, however, reported months of smoke escaping from beneath the soil from one of the depressions (personal communication Dudu Gumede, September 2013). This specific site (PL3) has a top soil content of 5.69% (although sampling did not take place at the exact same place as where the alleged underground fire occurred).

"If the soil form is Katspruit, Kroonstad, Longlands, Wasbank, Lamotte, Westleigh, Dresden, Avalon, Pinedene, Tukulu or Dundee, then the profile:

➢ *Has a dark topsoil (moist Munsell values of 4 or less and chroma values of 1 or less); and has a very high organic carbon topsoil content, usually more than 4% throughout the horizon"*

- See the comments about soil colour and carbon content in Fernwood soil forms above. Additionally – the amount of soil organic carbon content is strongly associated with the substrate type. In the duplex wetland types, for example, carbon content was rarely above 3%, while in the soil forms in the other wetland types it varied between 3% and 9%.

- Soil forms which classified as wetland soils in this study, but which are not included in the list above are Sterkspruit, Valsrivier, Kinkelbos, Montagu, and Sepane.

➢ *"Has signs of wetness within 50 cm of the soil surface"*

- This has been shown to not necessarily be true, and is discussed in detail in Section 9.2 of this chapter.

➢ *"Has a significant textural increase (within 50 cm of the soil surface) from the E or overlying horizon to the underlying soft plinthite, G horizon or unspecified material with signs of wetness, such that sandy profile textures in the E (or overlying horizons) become at least sandy clay loam in the underlying hydromorphic horizons"*

- This has been shown not to be necessarily true. It may sometimes only be a slight textural increase (e.g. apedal, Single grain; to Weak, Single grain). It seems as if textural properties in the Katspruit soil forms stay the same from the A horizon to the G horizon. This is discussed in more detail in Chapter 4.

"ii) Soil properties associated with the permanent and/or seasonal zone of wetness in riparian and wetland habitats on sandy coastal aquifers: pedological criteria are similar as described for the temporary zone of wetness. However, excessively high organic carbon topsoil occur (organic carbon content >10%) and topsoil are typically peaty. Soil form is commonly Champagne. However, the other soil forms (described above) having >10% organic carbon in the topsoil may also occur."

- As discussed already this statement is true, with only one exception: no other soil forms with soil organic carbon more than 10% exist if it is not the Champagne soil form.

Other comments on the delineation guideline:

- Currently the guideline is worded in such a manner as to suggest that the soil forms occurring in the seasonal/temporary zones are indicative of wetland conditions. It should be made clear that these soil forms could also be encountered outside the wetland boundary as non-wetland soil, if their indications of wetness are absent or fall outside the required identification depth.

- The statements in the guidelines that "...*the soils on the MCP typically exhibit grey profile colours which are not necessarily associated with hydromorphic soil forming processes, and may be a result of stripping of sesquioxides off mineral grains via podzolization within the profile. Such grey soils, especially on upland sites and midslope sites, are thus not associated with zones of saturation and are thus not indicative of riparian or wetland habitats*" was found to be accurate.

- The statements in the guidelines that wetland soils on the MCP lack the characteristic redoximorphic mottles due to the sandy nature of the soil was found to be incorrect, as redox accumulations and/or depletions were widely encountered throughout all the wetlands investigated (Chapter 5). These features are, however, often sporadic and unreliable, and do not present itself in the same way as the catena example in the delineation guideline (DWAF 2005). More research is needed to understand their presence and appearance.

- The delineation guidelines states that it is *"…a dynamic document, which will continue to evolve as the knowledge base for wetland delineation and riparian areas continues to grow in South Africa. Comments and suggestions on the manual will be incorporated in future editions*."

Although much work has been done to update the manual, nothing has been published yet. There is also much contention regarding what updated or new guidelines should look like. Despite the motivation and will to improve the manual, the reality is that very little research focusing exclusively on the science of wetland delineation, especially in the so-called 'problematic areas' has been done in the past 10 years. This is despite the fact that there has been much contribution to the wetland knowledge base by wetland scientists and practitioners during the past 10 years. The USDA-NRCS wetland delineation guideline (USDA-NRCS 2010) is possibly a good example of the format of a 'dynamic document'. This document bases the identification of hydric soil on a list of specific criteria or indicators, of which a soil profile only has to comply with one. Indicators can be added, deleted, revised, or refined through a specified process which includes data collection, peer review, testing, and research (USDA-NRCS 2010). This specific guideline focuses only on whether a site is hydric or not, and does not emphasise the identification of the various zones at all. The current guideline document (DWAF 2005) seemingly puts too much emphasis on the characteristics of the various zones. Although it is important to understand the change of the indicators along a catena, it becomes a vague and unreliable exercise to define each zone. In this study especially, it was found that the indicators rarely followed the 'textbook example' of where to find which indicators. Instead of trying to fit observations and data into the classic examples of what a specific zone should look like, the guidelines should rather supply a set of criteria which should be met in order to classify as a hydric site, whether it be permanent, seasonal, or temporarily wet sites. Following the example of the USDA-NRCS (2010), the indicators could be grouped in such a manner that a site only has to comply with one set of criteria in order to classify as a wetland site.

Chapter 10
CONCLUSIONS AND RECOMMENDATIONS

Sieben (2014) states that the MCP "seems to be one of the richest areas of wetlands in the country". The MCP is not only rich in the number of wetlands, but also in the diversity of wetland types (Grundling 2009, Matthews et al. 1999, Watkeys et al. 1993). Although it would be expected that wetland types in an area that is covered with leached, aeolian cover sands, and a hydrology that is groundwater driven would share many characteristics, this study has indicated that each of the five wetland types are each very unique in its own right. Consequently it is impossible to make broad statements about the soil and vegetation characteristics of the wetlands in general on the MCP. This has implications for documents such as the wetland delineation manual, which attempts to provide general guidelines on how any wetlands should be understood on all sandy coastal aquifers. This is discussed in detail in Chapter 9.

Three dominant substrate types are present in wetlands on the MCP which play a major influential role in the general characteristics, importance, and function of the wetland types.

- **High organic matter soils** (Muzi Swamp, Interdunal Depression, and Moist Grasslands) are linked to a high groundwater table, resulting in mostly permanent saturation of these horizons. Peat is found in both the Muzi Swamp and the Interdunal Depressions, although it does not dominate the whole wetland area. High organic matter soils (Champagne soil form) are found in the Moist Grasslands, where organic matter accumulation and saturated soil conditions can be found in sections within the seasonally flooded, flat upland area. The reasons for the high water table in the upland, sandy Moist Grasslands are discussed in Chapter 5.
- **Duplex soils** are associated with the seasonally flooded areas of the Muzi Swamp, as well as the seasonal perched pans (PP- and DP Types). Although the clay content of these wetland types are not exceptionally high, it appears that even a little clay has a huge influence on the MCP. All three these wetland types also have calcium carbonate in varying quantities present, due to close contact with the Uloa/Umkwelane geological Formation. Lateral ground water movement through and over this formation has resulted in the formation of this calcareous, duplex soils, as well as the high clay and calcium carbonate contents within the peat body of the Muzi Swamp. Although it is commonly accepted that clayey soils accumulate organic carbon more efficiently than sandy soils, a direct correlation between carbon- and clay content is only evident in the Moist Grasslands, and not in any of the clay wetland types.
- **Sandy soils** of aeolian and alluvial origin of the Moist Grasslands (excluding the high organic zones) and the Interdunal Depressions (excluding the peat zones) result in apedal, single grain soils with a loose, non-sticky and non-plastic consistency. The difference in slope gradient results in the hydrological dissimilarities in these two wetland types. Additionally

the profiles in the Moist Grasslands are pedogenically more developed and reworked, and probably older than the dunes amongst which the Interdunal Depressions occur.

It is generally accepted that redoximorphic accumulation and -depletions do not occur on the MCP. This study found plenty of these features, but to different extents in each wetland type. Redoximorphic accumulation and -depletions were found in abundance in the Muzi Swamp, and quite reliably indicated wetland conditions. In the Perched Pans these features were variable and unreliable, because it occurred in supposedly terrestrial sites, and in some cases not even in the wetland soils. Mottling was encountered in the sandy Moist Grasslands (but it was extremely inconsistent), and rarely in the Interdunal Depressions. It was present in some of the peat horizons (despite organic matter supposedly masking redoximorphic features). In all the wetland types mottles did not occur in the typical textbook style: they ranged from none in the upland areas, few in the temporary areas, many in the seasonal areas to none in the permanently wet areas. Within the sandy wetlands, especially the Moist Grasslands, it is hypothesised that redoximorphic accumulation and -depletions can appear and disappear rapidly following rain events, since sandy soil reduces faster, but also oxidizes faster than clay soils; and iron leaches faster (Vepraskas 2001, Vepraskas & Wilding 1983). According to Kotze et al. (1996) the relationship between the frequency and duration of saturation and the particular hydric soils and vegetation that develop as a result of saturation, is poorly understood.

Soil elements accumulate and deplete down the topographical gradient in different manners, and therefore the outcomes of a zone delineation exercise will be different every time another variable is used to look at differences between zones. The investigation whether statistically significant differences of soil properties down the topographical gradient can indicate wetland boundaries shows that of all the properties organic carbon is the most reliable. However, even organic carbon is not consistently applicable across all wetland types. Chemical soil properties are therefore not good indicators of wetland boundaries on the MCP, as these are extremely variable and also will be different in different wetland types. Although certain patterns can be discerned and possibly applied to determine wetland conditions, it is not a rapid field method.

Matthews (2007) found that the major determinants for vegetation communities in general everywhere on the MCP are water table, soil type, and topography. This study shows that this is also true for wetland vegetation specifically. The ordination results highlighted two environmental gradients. The strongest gradient is the wetness gradient, which is indicated by the soil properties organic carbon and soil resistance (i.e. low electrical conductivity). High organic carbon is strongly associated with permanently saturated soil (e.g. peatlands), whereas high soil resistance is associated with freely drained sandy soils. The secondary gradient is the productivity gradient, as indicated by high amounts of basic cations, iron, manganese, and pH. These soil properties are all associated with carbon, and to a lesser degree clay. The productivity of the soil (and therefore the productivity of the vegetation as well) decreases from the sites high in organic carbon and clay content, to the freely drained sandy soils characterized by high resistance. The use of vegetation composition via the ordination analyses approach was not very effective to indicate strictly defined wetness zones as is depicted in the examples in the delineation guideline (DWAF 2005).

A number of indicator plant species were defined, which indicate wetland and non-wetland conditions. Although the delineation guideline cautions against the use of individual indicator species, Chapter 7 shows that when the wetland types are evaluated individually, some prominent indicator species can be used for the delineation of zones as well as wetland and non-wetland sites. Without much in-depth research, this approach is, however, not viable as an umbrella-method for the whole country.

A relatively underutilised vegetation assessment procedure in South Africa called 'Weighted Averaging' (WA) was used to investigate the effectiveness of vegetation in the indication of wetland and non-wetland conditions. In some wetland types this approach was more effective than in others, but generally wetland types show a clear shift from the bottomland- to the upland zones on the topographical gradient. The Weighted Averaging categories are, however, not directly applicable to the wetness categories of DWAF (2005). Overall the WA approach appears to be a valuable and useful tool to apply in wetland science, and especially in delineation practices. However, it requires a list of wetland plant species and their indicator statuses. While a few such lists do exist for selected areas in the country (Day et al. 2010), these are not exhaustive for all areas in the country. The available lists often only include aquatic plants, are not coherently managed, and many are not commonly used or readily available. The species list used in this study that was developed by Glen (undated) is one of the most complete lists, but it is compiled on a national level, and therefore does not make provision for regional variability of species preferences. Such comprehensive lists per area in South Africa are required if one is to make use of the WA or other similar approaches.

Literature shows that there is a relationship between SOC and soil colour, although it is often a poor relationship, and is influenced by other characteristics such as soil texture and land-use. This study indicates that soil with dark colours can indicate either high or low SOC content, while lighter soil colours will always indicate low SOC content. Segmented Quantile Regressions indicate that potentially maximal SOC contents will occur at values of low colour indices, and predictably minimal SOC contents will occur at values of low or high colour indices. Using the regression equations, threshold values can be determined and used to make assumptions. An example of this is "When the sum of dry and wet Value and Chroma values is 9 or more, SOC content will be 4.79% and less". This assumption was the best correlated (r^2 = 0.91). Threshold values such as in the above mentioned example (9) can be used to differentiate between wetland and non-wetland sites. The comparison of the results to the soil and vegetation indicators indicated a 70 – 100% effectiveness for this method using threshold values. This implies that soil colour can indeed be used to indicate wetland boundaries. However, it would seem as if there is much variation between the effectiveness of the various indices within the various wetland types (with the Muzi Swamp being the most predictable, and the Moist Grasslands the least predictable). The implication of this is that threshold values would have to be developed for each wetland type separately before colour can reliably be used as an indicator of wetland boundaries. The various indices also need to be tested extensively with a much larger dataset in order to improve the threshold values.

Chapters 7, 8, and 9 showed that the vegetation and soil indicators do not correlate perfectly. The soil indicator often indicates wetness when the vegetation indicator indicates upland conditions. Vegetation is known to indicate fluctuating environmental conditions much more readily than the soil, but because of the sandy soil in some of the wetland types the soil indicators appear and disappear just as quickly. The current drought might emphasise this variability even more. The implication for delineation is that wetlands cannot be delineated by means of one indicator only, and as much information as possible should be collected (Day et al. 2010, Job 2009). The use of - for example - not only the terrain unit, but also the slope gradient of wetlands on the MCP is important; and the combined effect of the substrate type and the terrain characteristics on the hydrological regime should always be evaluated. Delineation in cryptic wetlands such as the Moist Grasslands is very complicated, and alternative methods such as interviews with the local residents around the wetlands; or assessment of aquatic invertebrate communities (Day et al. 2010) should be applied in addition to the evaluation of the normal indicators. For this reason the use of the colour indices provided in this study is recommended, although much more research is required for the refinement thereof.

Kotze et al. (1996) state that the USA soil classification should rather be used to classify the hydric soils of South Africa. However, with the current 1991 revision of the South African soil classification system it is rather advised that this classification be refined to account better for hydromorphic soil conditions. The guideline is currently worded in a manner to suggest that the soil forms occurring in the seasonal/temporary zones are indicative of wetland conditions. It should be made clear that these soil forms could also be encountered outside the wetland boundary as non-wetland soil, if indications of wetness are absent or fall outside the required identification depth. More research is also required on the variation of redoximorphic features down the topographical gradient, and its relation to the other wetland indicators.

The current wetland delineation procedure in South Africa is based on the DWAF (2005) delineation manual. There is, however, little research and data that focus specifically on the identification of wetland boundaries to improve the understanding and implementation of this delineation approach. Ideally South Africa, or at least the areas in the country that experience difficulties with delineation, should adopt the approach of the USDA-NRCS where regionally specific guidelines are designed to be adapted regularly as new information becomes available. Such guidelines and adaptive processes do not currently exist in South Africa. Wetland delineation guidelines with sets of indicators specific to problematic areas should be developed.

Large parts of South Africa have very variable climates, resulting in the wetlands being much more variable than in other parts of the world (such as seasonal and temporary wetlands). This is more pronounced at the outer boundary areas of the wetland. This study has shown that strictly defined wetness zones are not viable, at least not on the MCP. The seasonally flooded zones are very transitory in particular, and therefore variable, even within wetlands of the same wetland type. However, the upland zones are usually very characteristic. Wetland delineation practices should therefore rather focus on the determination of wetland and non-wetland conditions.

All objectives set for this study were successfully achieved: The soil characteristics of five different wetland types along a topographical gradient were established and discussed. While it was determined that differences between the typical soil characteristics on various positions on the slope do exist and can probably reveal a lot of the characteristics of the wetland, no chemical soil property is suitable to use for zone, or wetland delineation. Although the use of vegetation composition via the ordination analyses approach is not effective to indicate strictly defined zones of wetness, a number of indicator plant species can indicate wetland and non-wetland conditions. Additionally, the 'Weighted Averaging' approach was shown to be practical to indicate wetland and non-wetland conditions, although not directly applicable to the wetness categories of DWAF (2005). Soil colour has been shown to be able to indicate wetland boundaries successfully. The method still requires much testing, however.

Very few investigative studies into the soil and vegetation characteristics of specifically wetlands exist on the Maputaland Coastal Plain. This is regarded as a large gap in scientific knowledge. The aim of this study was to add to this pool of knowledge, and has successfully done so. Additionally, the study has contributed to concrete research data and understanding on how wetland properties vary down the topographical slope in wetlands on sandy coastal aquifers in order to inform wetland delineation.

Recommendations

- A much more in-depth study of the drivers of the variable redox morphology of the study area is warranted.
- The Weighted Averaging approach to delineation wetland vegetation zones should be refined.
- There is a need for a region-specific list of the hydric status of plant species on a national scale.
- The soil colour indices need to be refined using a larger dataset, and determined for more wetland types on the MCP. Thereafter testing of the indices is required.
- A broad wetland delineation process cannot be applied to the problematic areas in South Africa, as defined by DWAF (2005). A list of hydric site indicators or criteria specific to each of these sites needs to be developed.
- An updated edition of the wetland delineation manual, which will take into account recent research and studies such as this study and that by Job (2009) should be developed.
- A strategic management plan for wetlands on the MCP is necessary to manage the numerous threats to especially the sensitive wetland systems such as peatlands.

Chapter 11
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Profile No: MS6-01

S -26.997010° E 32.505649°

Soil form:	Champagne	**Soil family:**	
Described by:	LP	**Date described:**	09/2012
Water table:	400	**Altitude:**	
Terrain unit:	Valley Bottom	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	Other mounds:burnt peat
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	1200	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, Fine, Faint, Red, Oxidized iron oxide; **Secondary Mottles:** s.a.a. Red&brown, Illuvial iron & humus; **Structure:** Apedal, Massive; **Consistence**:Very hard, Friable, Non-sticky, non-plastic; **Pores & cracks:** Many, Normal, No cracks ; **Cementation:** Moderate; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Common; **Transition:**	Organic O	Water and chalk layer at 400mm. Burnt peat mounds

Profile No: MS6-02

S -26.997198° E 32.505961°

Soil form:	Champagne	**Soil family:**	
Described by:	LP	**Date described:**	09/2012
Water table:	500	**Altitude:**	
Terrain unit:	Valley Bottom	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	?	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Common, Coarse, Prominent, Reddish brown, Illuvial iron and humus; **Structure:** Weak, Medium, Granular; **Consistence**:Hard, Friable, Non-sticky, non-plastic; **Pores & cracks:** Common, Normal, No cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Many; **Transition:** Abrupt, smooth	Organic O	Water and chalk at 500-600mm. Seems as if water is moving on top of chalk.
C	?	**Moisture status:** Wet; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, Coarse, Prominent, Black, Illuvial humus; **Secondary mottles**: s.a.a., Yellow, Oxidized iron oxide; **Structure:** Apedal, Massive; **Consistence**:Soft, Loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 4s; **Roots:** Common; **Transition:**	Unspecified material with signs of wetness	

Profile No: MS6-03

S -26.997302° E 32.506579°

Soil form:	Fernwood	**Soil family:**	
Described by:	LP	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Lower midslope	**Flood occurrence:**	Occasional
Slope: %	2	**Microrelief:**	None
Slope shape:	Concave	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	500	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Many, Coarse, Distinct, Red, Oxidized iron oxide; **Structure:** Weak, Medium, Granular; **Consistence**:Hard, Firm, Sticky, Slightly plastic; **Pores & cracks:** Common, Normal, No cracks ; **Cementation:** none; **Lime:** Moderate; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 5s; **Roots:** Many; **Transition:** Gradual, Tonguing	Orthic A	Thick red layer at 200 mm, probably burnt peat. Sand at 500mm. Two elephants.

E	1200	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, Coarse, Distinct, Black, Illuvial humus; **Secondary mottles**: s.a.a., Red, Reduced iron oxides; **Tertiary mottles:** s.a.a. White, Reduced iron oxide; **Structure:** Apedal, Single grain; **Consistence**: Loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:**	E	

Profile No: MS6-04

S -26.997579° E 32.507521°

Soil form:	Brandvlei	**Soil family:**	
Described by:	LP	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Upper midslope	**Flood occurrence:**	None
Slope: %	3	**Microrelief:**	Anthill mounds
Slope shape:	Concave	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Grassveld, closed
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	100	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:loose, friable, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime: Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Many; **Transition:** Abrupt, smooth	Orthic A	Wetter to the bottom. The relationship between reduction and oxidation close to each other is important as it says a lot about the conditions
C	1200	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, Fine, Faint, Grey & yellow, Oxidized and reduced iron oxides; **Structure:** Apedal, single grain; **Consistence**:loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime: Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Gradual, smooth	Soft Carbonate	

Profile No: MS4-01

S -27.013466° E 32.500891°

Soil form:	Champagne	**Soil family:**	
Described by:	LP/CvH	**Date described:**	09/2012
Water table:	700	**Altitude:**	
Terrain unit:	Valley bottom	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	700	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Strong, Medium, Granular; **Consistence**:Loose, Loose, Non-Sticky, Non-plastic; **Pores & cracks:** Common, Normal, No cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:** Abrupt, Smooth	Organic O	Burnt black sand and water at 700mm
C	1200	**Moisture status:** Wet; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, Medium, Faint, Grey, Reduced iron oxide; **Structure:** Apedal, Single grain; **Consistence**: Slightly hard, Firm, Slightly-Sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:**	Unspecified material with signs of wetness	

Profile No: MS4-02

S -27.013556° E 32.501380°

Soil form:	Champagne	**Soil family:**	
Described by:	LP/CvH	**Date described:**	09/2012
Water table:	1000	**Altitude:**	
Terrain unit:	Valley bottom	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown

Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	1000	**Moisture status:** Wet; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Common, Coarse, Distinct, Reddish brown, Illuvial iron and humus; **Secondary mottles:** s.a.a., White, Lime; **Structure:** Strong, Coarse, Granular; **Secondary structure:** Strong, Medium, Angular blocky; **Consistence**:Hard, Friable, Non-Sticky, Non-plastic; **Pores & cracks:** Many, Normal, No cracks ; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Many; **Transition:** Clear, Smooth	Organic O	Ash layer at 300mm; chalk layer and water table at 1000mm
C	1200	**Moisture status:** Wet; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Many, Coarse, Prominent, White, Lime; **Structure:** Apedal, Massive; **Consistence**: Very hard, Loose, Slightly-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:**	Unspecified material with signs of wetness	

Profile No: MS4-04

S -27.013683° E 32.502128°

Soil form:	Westleigh	**Soil family:**	
Described by:	LP	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Upper footslope	**Flood occurrence:**	Occasional
Slope: %	1	**Microrelief:**	Other mounds
Slope shape:	Concave	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	300	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, Fine, Distinct, Grey, Reduced iron oxide; **Secondary mottles**: s.a.a. Red, Oxidized iron oxide; **Structure:** Moderate, Coarse, Granualr; **Consistence**:Very hard, Firm, Sticky, Plastic; **Pores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Many; **Transition:** Abrupt, Smooth	Orthic A	
B	1200	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Many, Coarse, Prominent, White,White bleached;Secondary mottles: s.a.a., Yellow, brown and red, Oxidized iron oxide; **Tertiary mottles:** s.a.a. White, Reduced iron oxide; **Structure:** Apedal, Massive; **Consistence**: Very hard, Firm, Sticky, Plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** None; **Transition:**	Soft Plinthic B	

Profile No: MS1-01

S -27.008536° E 32.503105°

Soil form:	Champagne	**Soil family:**	
Described by:	LP/CvH	**Date described:**	06/2010
Water table:	N/R	**Altitude:**	
Terrain unit:	Valley Bottom	**Flood occurrence:**	Frequent
Slope: %		**Microrelief:**	Other mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single: Alluvium	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

O	360	**Moisture status:** Moist; **Colour:** 10YR2/1 6% **clay;** **Mottles:** Few, Coarse, Distinct, Grey, Reduced iron oxide; **Secondary mottles:** Few, Medium, Faint, Red, Oxidised iron oxide; **Structure:** Strong, Coarse, Granular; **Consistence**:Soft, Friable, Non-Sticky, Plastic; **Pores & cracks:** Few, Normal, Fine cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** Alluvial; **Water absorption:** 1s; **Roots:** Many; **Transition:** Clear, Smooth	Organic O
C1	450	**Moisture status:** Moist; **Colour:** 10YR7/1 20% **clay;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Soft, Friable, Non-Sticky, Plastic; **Pores & cracks:** Few, Rusty streaking, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** Alluvial; **Water absorption:** 2s; **Roots:** Common; **Transition:** Clear, Smooth	Soft carbonate
C2	800	**Moisture status:** Moist; **Colour:** 7.5YR4/1 18% **clay;** **Mottles:** Few, Medium, Faint, Red, Oxidized iron oxide; **Structure:** Apedal, Massive; **Consistence**:Soft, Friable, Non-Sticky, Plastic; **Pores & cracks:** Few, Rusty streaking, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** Alluvial; **Water absorption:** 1s; **Roots:** Common; **Transition:** Gradual, Smooth	Soft carbonate
C3	1200	**Moisture status:** Moist; **Colour:** 10YR3/1 45% **clay;** **Mottles:** Few, Fine, Faint, Grey, Reduced iron oxide; **Secondary mottles:** Few, Fine, Faint, Red, Oxidized iron oxide; **Structure:** Apedal, Massive; **Consistence**:Soft, Friable, Non-Sticky, Plastic; **Pores & cracks:** Few, Rusty streaking, No cracks; **Cementation:** none; **Lime:** Moderate; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** Alluvial; **Water absorption:** 2s; **Roots:** Few; **Transition:**	Unspecified material with signs of wetness

Profile No: MS1-02

S -27.008882° E 32.503567°

Soil form:	Champagne	**Soil family:**	
Described by:	LP/CvH	**Date described:**	06/2010
Water table:	1200mm	**Altitude:**	
Terrain unit:	Valley Bottom	**Flood occurrence:**	Frequent
Slope: %		**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None

Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	1200	**Moisture status:** Moist; **Colour:** 10YR2/1 6% **clay;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Soft, Friable, Non-Sticky, Plastic; **Pores & cracks:** Few, Normal, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** Alluvial; **Water absorption:** 1s; **Roots:** Many; **Transition:**	Organic O	1. Lime lenses occur below 500 - 1200mm. Lenses are 80mm thick and almost continuous. Almost no organic carbon in the lenses. White. 2. Profile in Cladium vegetation zone

Profile No: MS1-03

S -27.009019° E 32.503894°

Soil form:	Westleigh	**Soil family:**	
Described by:	LP/CvH	**Date described:**	06/2010
Water table:	N/R	**Altitude:**	
Terrain unit:	Midslope	**Flood occurrence:**	Occasional
Slope: %	5	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	240	**Moisture status:** Dry; **Colour:** 10YR4/12% **clay;** **Mottles:** Few, Fine, Faint, Yellow, Oxidized iron oxide; **Structure:** Strong, Medium, Granular; **Consistence**:Loose,Non-Sticky, Non-plastic; **Pores & cracks:** Common, Normal, Fine; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Many; **Transition:** Clear, Smooth	Orthic A	1. Bleached layer of 2cm thick organic matter and occurs below the B

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
B	450	**Moisture status:** Dry; C**olour:** 7.5YR2.5/1; 35% **clay;** M**ottles:** Many, Coarse, Prominent, Yellow, Oxidized iron oxide; **Structure:** Strong, Coarse, Granular; **Consistence**: Slightly hard, Friable, Non-sticky, Slightly-plastic; P**ores & cracks:** Common, Normal, Fine; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Common; **Transition:** Clear, Smooth	Soft Plinthic B	2. In the Imperata vegetation zone
C1	650	**Moisture status:** Dry; C**olour:** 10YR6/2; 3% **clay;** M**ottles:** Few, Coarse, Faint, Yellow, Oxidized iron oxide; **Secondary mottles:** Few, Fine, Faint, Black, Illuvial humus; **Structure:** Apedal, Massive; **Consistence**: Slightly hard, Loose, Non-sticky, Non-plastic; P**ores & cracks:** Few, Normal, no cracks; **Cementation:** none; **Lime:** Moderate; **Slickensides:** none; **Cutans:** None; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Common; **Transition:** Gradual, Smooth	Unspecified material with signs of wetness	
C2	1200	**Moisture status:** Moist; C**olour:** 10YR6/6; 15% **clay;** M**ottles:** Many, Coarse, Prominent, Gray, reduced iron oxide; **Secondary mottles:** Few, Fine, Faint, Black, Illuvial humus; **Structure:** Apedal, Massive; **Consistence**: Hard, Loose, Non-sticky, Non-plastic; P**ores & cracks:** Few, Bleached, no cracks; **Cementation:** none; **Lime:** Moderate; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Common; **Transition:**	Unspecified material with signs of wetness	

Profile No: MS1-04

S -27.009170° E 32.504102°

Soil form:	Longlands	**Soil family:**	
Described by:	LP/CvH	**Date described:**	06/2010
Water table:	N/R	**Altitude:**	
Terrain unit:	Crest	**Flood occurrence:**	None
Slope: %		**Microrelief:**	Anthill mounds
Slope shape:	Concave	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, closed
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	170	**Moisture status:** Dry; **Colour:** 7.5YR3/1; 9 % **clay;** **Mottles:** None; **Structure:** Apedal, Single grain **Consistence**:Loose,Non-Sticky, Non-plastic; **Pores & cracks:** Many, Normal, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Many; **Transition:** Clear, Smooth	Orthic A	1. Probably a paleosol: E and Sp horizons developing in an old Estcourt 2. Water moving lateral in E and Orthic horizons
E	330	**Moisture status:** Dry; **Colour:** 5YR6/1; 12 % **clay;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**: Soft, Friable, Non-sticky, Non-plastic; **Pores & cracks:** Many, Normal, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:** Clear, Smooth	E	Terrestrial vegetation, almost between trees
B	450	**Moisture status:** Dry; **Colour:** 10YR6/8; 18 % **clay;** **Mottles:** Common, Medium, Distinct, Gray, Reduced iron oxide; **Structure:** Apedal, Massive; **Consistence**: Hard, Friable, Slightly-sticky, Non-plastic; **Pores & cracks:** Many, Normal, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** Few, Skeletans; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Clear, Smooth	Soft Plinthic B	
C1	570	**Moisture status:** Dry; **Colour:** 7.5YR8/2; 20% **clay;** **Mottles:** Common, Medium, Faint, Yellow, Oxidized iron oxide; **Structure:** Apedal, Massive; **Consistence**: Very hard, Friable, Slightly-sticky, Non-plastic; **Pores & cracks:** Many, Normal, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** None; **Transition:** Clear, Smooth	Unspecified material with signs of wetness	
C2	1200	**Moisture status:** Moist; **Colour:** 10YR8/8; 25% **clay;** **Mottles:** Common, Coarse, Distinct, Gray and yellow, Reduced iron oxide; **Secondary mottles:** Few, Medium, Prominent, Black, Illuvial humus; **Structure:** Apedal, Massive; **Consistence**: Very hard, Friable, Slightly-sticky, Non-plastic; **Pores & cracks:** Many, Normal, No cracks; **Cementation:** none; **Lime:** Strong; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** None; **Transition:**	Unspecified material with signs of wetness	

Profile No: MS4-05

Soil form:	Brandvlei	S -27.013695° E 32.502365°	**Soil family:**	
Described by:	LP		**Date described:**	09/2012

Water table:	N/R	**Altitude:**	
Terrain unit:	Upper footslope	**Flood occurrence:**	None
Slope: %	1	**Microrelief:**	Anthill mounds
Slope shape:	Concave	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Grassveld, sparse
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	150	**Moisture status:** Moist; C**olour:** 10YR4/2; 8.9 % **clay;** M**ottles:** Common, Fine, Faint, Grey, Reduced iron oxide; **Secondary mottles**: s.a.a., Black, Illuvial humus; S**tructure:** Weak, Coarse, Granualr; **Consistence**:Hard, Firm, Slightly sticky, Slightly plastic; P**ores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides: N**one; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Clear, Tonguing	Orthic A	Hard plinthic B is very hard and impermeable
B1	800	**Moisture status:** Moist; C**olour:** 10YR4/2; 8.9 % **clay;** M**ottles:** Common, Medium, Distinct, Yellow, Oxidized iron oxide; **Secondary mottles:** s.a.a., Black, Illuvial humus; **Tertiary mottles:** s.a.a. White, Reduced iron oxide; **Structure:** Apedal, Massive; **Secondary structure:** Moderate, Coarse, Angular blocky; **Consistence**: Soft, Slightly firm, Sticky, Non-plastic; P**ores & cracks:** few, normal, fine cracks ; **Cementation:** none; **Lime:** Moderate; **Slickensides: N**one; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 3s; **Roots:** None; **Transition:** Abrupt, Tonguing	Soft carbonate	
B2	1200	**Moisture status:** Moist; C**olour:** 10YR4/2; 8.9 % **clay;** M**ottles:** None; **Structure:** Strong, Coarse, Massive; **Consistence**: Very hard, Very firm, Non-sticky, Non-plastic; P**ores & cracks:** few, normal, fine cracks ; **Cementation:** none; **Lime:** Moderate; **Slickensides: N**one; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	Hard plinthic B	

Profile No: PP1-01			
Soil form:		**Soil family:**	
	S -27.023101° E 32.491910°		
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	-400	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	Other mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Marsh; treeveld, closed
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
		Inundated to such an extent that sampling is impossible		

Profile No: PP1-02			
Soil form:	Katspruit	**Soil family:**	
	S -27.023101° E 32.491910°		
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	-300	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	Other mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Marsh; treeveld, closed
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	100	**Moisture status:** Wet; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, fine, faint, Grey, yellow and olive, Oxidized iron oxide **Structure:** Moderate, Coarse, Angular blocky; **Consistence**:Very hard, Very firm, Sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** Common,Skeletans; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** common **Transition:** Clear, Tonguing	Orthic A	Cutanic character. Ped is dry inside. Clay ped with sand cutan and that is where the water moves (skeletan)

G	1200	**Moisture status:** Wet; **Colour:** 10YR5/4; 8.9 % **clay;** M**ottles:** Few, fine, Distinct, Red and yellow, Oxidized iron oxide; S**tructure:** Weak, Coarse, Angular blocky; **Consistence:** Very hard, Very firm, Very sticky, Plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** Common,Skeletans; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** none; **Transition:**	G	

Profile No: PP1-03

S -27.023101° E 32.491910°

Soil form:	Sterkspruit	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Upper midslope	**Flood occurrence:**	None
Slope: %	1	**Microrelief:**	Anthill mounds
Slope shape:	Concave	**Surface covering:**	None
Aspect:	North	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Treeveld, closed
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	150	**Moisture status:** Moist; C**olour:** 10YR4/2; 8.9 % **clay;** M**ottles:** None; S**tructure:** Weak, Medium, Crumb. **Secondary structure:** Weak, Coarse, Prismatic; **Consistence**:Soft, Friable, Slightly sticky, Non-plastic; P**ores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** Few, Skeletans; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:** Clear, Smooth	Orthic A	Mottles are faint and only at 200mm in the chalk
B	500	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** M**ottles:** Few, fine, Faint, Yellow, Oxidized iron oxide; **Structure:** Weak, Medium, Crumb. **Secondary structure:** Weak, Coarse, Angular blocky; **Consistence:** Slightly hard, Firm, Slightly sticky, Non-plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** Few, Skeletans; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Common; **Transition:** Clear, Smooth	Prismacutanic B	

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
C	1200	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, Faint, Yellow, Oxidized iron oxide; **Structure:** Apedal, single grain; **Consistence:** Loose, Loose, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** None; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** none; **Transition:**	Unspecified material, with signs of wetness	

Profile No: PP3-01

S -27.026788° E 32.489414°

Soil form:		**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2010
Water table:	N/R	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Occasional
Slope: %	0	**Microrelief:**	None
Slope shape:	Concave	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	?	**Moisture status:** Dry; **Colour:** 7.5YR2.5/1; 35% **clay;** **Mottles:** Few, Fine, Faint, Red, Oxidized iron oxide; **Secondary mottles**: Few, Coarse, Faint, Yellow, Oxidized iron oxide; **Structure:** Strong, Coarse, Prismatic; **Consistence**:Very hard, Very firm, Slightly-sticky, Slightly-plastic; **Pores & cracks:** Few, Normal, Fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** None; **Coarse fragments: N**one; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:** Gradual, smooth	Orthic A	

G	?	**Moisture status:** Dry; **Colour:** 10YR8/3; 35% **clay;** **Mottles:** Few, Medium, Distinct, Yellow, Oxidized iron oxide; **Secondary mottles:** Common, Coarse, Prominent, Grey, Reduced iron oxide; **Structure:** Strong, Coarse, Prismatic; **Secondary structure:** Strong, coarse, angular blocky; **Consistence**:Very hard, Very firm, Slightly-sticky, Slightly-plastic; **Pores & cracks:** Few, Normal, Fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** None; **Cutans:** Common, Skeletans; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:**	G	

Profile No: PP3-02

S -27.026788° E 32.489414°

Soil form:	Katspruit	**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2010
Water table:	N/R	**Altitude:**	
Terrain unit:	Lower footslope	**Flood occurrence:**	None
Slope: %	4	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	North	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, closed
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	500	**Moisture status:** Dry; **Colour:** 10YR2/1; 35% **clay;** **Mottles:** Few, Coarse, Grey, Reduced iron oxide; **Secondary mottles**: Few, Coarse, Distinct, Red, Oxidized iron oxide; **Structure:** Strong, Coarse, Prismatic; **Consistence**:Very hard, Very firm, Non-sticky, Slightly-plastic; **Pores & cracks:** Few, Normal, Fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** Few, Organic **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Gradual, Smooth	Orthic A	

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
G	1200	**Moisture status:** Dry; **Colour:** 10YR5/2; 25% **clay;** **Mottles:** Few, Medium, Faint, Red, Oxidized iron oxide; **Secondary mottles:** Many, Coarse, Distinct, Yellow, Oxidized iron oxide; **Structure:** Strong, Coarse, Prismatic; **Consistence**:Very hard, Very firm, Slightly-sticky, Slightly-plastic; **Pores & cracks:** Few, Normal, Fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** Few; **Cutans:** Few, Skeletans; **Coarse fragments:** Very few, Lime concretions, Fine, Round; **Features:** none; **Stratification:** none; **Water absorption:** 3s; **Roots:** Few; **Transition:**	G	

Profile No: PP3-03

S -27.026788° E 32.489414°

Soil form:	Valsrivier	**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2010
Water table:	N/R	**Altitude:**	
Terrain unit:	Upper footslope	**Flood occurrence:**	None
Slope: %	6	**Microrelief:**	None
Slope shape:	Concave	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Thicket
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	150	**Moisture status:** Dry; **Colour:** 5YR3/1; 20% **clay;** **Mottles:** Common, Fine, Prominent, Red, Oxidized iron oxide; **Secondary mottles**: Few, Fine, Prominent, Yellow, Oxidized iron oxide; **Structure:** Apedal, Massive; **Consistence**:Hard, Firm, Slightly-sticky, Slightly-plastic; **Pores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** None; **Coarse fragments: N**one; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Common; **Transition:** Clear, Wavy	Orthic A	Very interesting soil profiel. Gilgai present.
B	1200	**Moisture status:** Dry; **Colour:** 7.5YR2.5/1; 35% **clay;** **Mottles:** None; **Structure:** Strong, Massive, Prismatic; **Consistence**:Very hard, Firm, Slightly-sticky, Slightly-plastic; **Pores & cracks:** Few, Normal, Fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** Many; **Cutans:** Few, Clay; **Coarse fragments:** Very few, Lime concretions, Medium, Round; **Features:** none; **Stratification:** none; **Water absorption:** 3s; **Roots:** Few; **Transition:**	Pedocutanic B	

Profile No: PP2-01			
Soil form:	Sterkspruit	S -27.024861° E 32.490222°	**Soil family:**	
Described by:	LP, CvH	**Date described:**	
Water table:	400	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	500	**Moisture status:** Moist; C**olour:** 5YR3/1; 20% **clay;** M**ottles:** None; S**tructure:** Moderate, Coarse, Granular; **Consistence**:Hard, Slightly firm, Slightly-sticky, Slightly-plastic; P**ores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime: Slickensides:** none; **Cutans:** Common, Skeletans; **Coarse fragments: N**one; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:** Clear, Smooth;	Orthic A	
B	1200	**Moisture status:** Wet; C**olour:** 7.5YR2.5/1; 35% **clay;** M**ottles:** Few, Fine, Faint, Yellow, Reduced iron oxide; S**tructure:** Strong, Coarse, Prismatic; **Consistence**:Hard, Firm, Sticky, Slightly-plastic; P**ores & cracks:** Few, Normal, no cracks ; **Cementation:** none; **Lime: Slickensides:** None; **Cutans:** Common, Skeletans; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:**	Prismacutanic B	

Profile No: PP2-02			
Soil form:	Sterkspruit	S -27.024861° E 32.490222°	**Soil family:**	
Described by:	LP, CvH	**Date described:**	
Water table:	400	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None

Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	500	**Moisture status:** Wet; **Colour:** 5YR3/1; 20% **clay;** **Mottles:** None; **Structure:** Moderate, Coarse, Angular blocky; **Secondary structure:** Moderate, Medium, Granular; **Consistence**:Hard, Firm, Slightly-sticky, Non-plastic; **Pores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** None; **Coarse fragments: N**one; **Features:** none; **Stratification:** none; **Water absorption:** 3s; **Roots:** Few; **Transition:** Clear, Smooth;	Orthic A	The A-horizon is thoroughly wet. To the bottom of the profile peds are wet on the outside but dry on the inside
B	1200	**Moisture status:** Wet; **Colour:** 7.5YR2.5/1; 35% **clay;** **Mottles:** Few, Common, Coarse, Prominent, Grey, Reduced iron oxide; **Secondary mottles**: s.a.a. Red and yellow, Oxidized iron oxide; **Structure:** Strong, Coarse, Prismatic; **Consistence**:Very hard, Very firm, Very sticky, Plastic; **Pores & cracks:** Few, Normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** None; **Cutans:** Many, Skeletans; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 6s; **Roots:** None; **Transition:**	Prismacutanic B	

Profile No: PP2-03

S -27.024861° E 32.490222°

Soil form:	Sterkspruit	**Soil family:**	
Described by:	LP, CvH	**Date described:**	
Water table:	N/R	**Altitude:**	
Terrain unit:	Midslope	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Other mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,Aeolian&Alluv	**Vegetation/Land use:**	Treeveld, closed
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	300	**Moisture status:** Moist; C**olour:** 5YR3/1; 20% **clay;** M**ottles:** None; S**tructure:** Apedal, Single grain; **Consistence**:Loose, Slightly-sticky, Slightly plastic; P**ores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** None; **Coarse fragments: N**one; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Gradual, Smooth;	Orthic A	Chalk from 500mm, which is the water line. So there could be chalk in zones 1 and 2 also
B	1200	**Moisture status:** Moist; C**olour:** 7.5YR2.5/1; 35% **clay;** M**ottles:** Few, Fine, Prominent, White, Lime; S**tructure:** Strong, Medium, Prismatic; **Secondary structure:** Weak, Coarse, Granular; **Consistence**:Hard, Firm, Slightly sticky, Slightly-plastic; P**ores & cracks:** Few, Normal, no cracks ; **Cementation:** none; **Lime:** Moderate; **Slickensides:** None; **Cutans:** None; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** None; **Transition:**	Prismacutanic B	

Profile No: DP1-01		S -27.066029° E 32.473304°		
Soil form:	Westleigh		**Soil family:**	
Described by:	LP		**Date described:**	06/2012
Water table:	N/R		**Altitude:**	
Terrain unit:	Closed depression		**Flood occurrence:**	Frequent
Slope: %	N/A		**Microrelief:**	None
Slope shape:	Straight		**Surface covering:**	None
Aspect:	Level		**Surface rockiness:**	None
Wind erosion:	None		**Weathering of underlying material:**	Unknown
Water erosion:	None		**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary:Aeolian&Alluv		**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous			

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	250	**Moisture status:** Moist; **Colour:** 2.5Y2/1; 8.9 % **clay;** **Mottles:** None; **Structure:** Weak, Fine, Single grainr; **Consistence**:Very hard, Firm, Sticky, Plastic; **Pores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:** Clear, smooth;	Orthic A	
B	1200	**Moisture status:** Moist; **Colour:** 2.5Y2/1; 8.9 % **clay;** **Mottles:** Many, Coarse, Distinct, Red, Oxidized iron oxide; **Secondary mottles** : Many, Coarse, Distinct, Yellow, Oxidized iron oxide; **Structure:** Moderate, Coarse, Angular blocky; **Consistence**: Very hard, Very firm, Slightly sticky, Slightly plastic; **Pores & cracks:** Few, Normal, Fine cracks ; **Cementation:** none; **Lime:** **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:**	Soft Plinthic B	

Profile No: DP1-02		S -27.066029° E 32.473304°		
Soil form:	Longlands		**Soil family:**	
Described by:	LP		**Date described:**	06/2012
Water table:	N/R		**Altitude:**	
Terrain unit:	Closed depression		**Flood occurrence:**	Occasional
Slope: %	1		**Microrelief:**	Anthill mounds
Slope shape:	Concave		**Surface covering:**	None
Aspect:	North-west		**Surface rockiness:**	None

Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	250	**Moisture status:** Dry; **Colour:** 10YR2/1; 8.9 % **clay;** **Mottles:** Few, Medium, Faint, Yello and black, Oxidized iron oxide; **Structure:** Apedal, Single grain; **Consistence**:Slightly hard, Firm, Sticky, Slightly plastic; **Pores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** Nonel **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:** Clear, smooth;	Orthic A	
E	700	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Weak, Fine, Single grain; **Consistence**: Loose, Slightly firm, Slightly sticky, Slightly plastic; **Pores & cracks:**Few, Normal, No cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:** Gradual, smooth	E	
B	1200	**Moisture status:** Moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Common, Medium, Distinct, Yellow and black, Reduced iron oxide; **Secondary mottles:** s.a.a., Black; **Structure:** Weak, Fine, Single grain; **Consistence**: Loose, Non-sticky, Non-plastic; **Pores & cracks:**Few, Normal, No cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	Soft Plinthic B	

Profile No: DP1-03

S -27.066029° E 32.473304°

Soil form:	Kinkelbos	**Soil family:**	
Described by:	LP	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Upper midslope	**Flood occurrence:**	Occasional
Slope: %	1	**Microrelief:**	Anthill mounds
Slope shape:	Concave	**Surface covering:**	None
Aspect:	North-west	**Surface rockiness:**	None

Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown/calcified?
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, sparse
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	100	**Moisture status:** Dry; **Colour:** 10YR2/1; 8.9 % **clay;** **Mottles:** Few, Fine, Faint, Reddish brown, Oxidized iron oxide; **Structure:** Apedal, Single grain; **Consistence**:Loose, Non-sticky; **Pores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** Moderate; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** Very few, Lime concretions, Medium, Round; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:** Abrupt, Smooth	Orthic A	
E	900	**Moisture status:** Dry; **Colour:** 7.5YR5/2; 8.9 % **clay;** **Mottles:** Common, Medium, Prominent, Yellow, brown and red, Oxidized iron oxide; **Structure:** Apedal, Single grain; **Consistence**: Soft, Loose, Non-sticky; **Pores & cracks:** Few, Normal, No cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** Very few, Lime concretions, Medium, Round**;** **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:** Gradual, Wavy	E	
B	1200	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Weak, Medium, Single grain; **Consistence**: Slightly hard, Slightly firm, Non-sticky; **Pores & cracks:** Few, Normal, No cracks; **Cementation:** none; **Lime:** Slight **Slickensides:** none; **Cutans:** Very many, Clay & Carbonate; **Coarse fragments:** Few, Lime concretions, Medium, Round **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	Neocarbonate B	

Profile No: DP1-04

S -27.066029° E 32.473304°

Soil form:	Longlands	**Soil family:**	
Described by:	LP	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Crest	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Anthill mounds
Slope shape:	Concave	**Surface covering:**	None
Aspect:	North-west	**Surface rockiness:**	None

Wind erosion:	None	**Weathering of underlying material:**	Unknown
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Treeveld, sparse
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	150	**Moisture status:** Dry; **Colour:** 10YR3/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, Single grain; **Consistence**:Loose, Non-sticky, Non-plastic; **Pores & cracks:** Common, Normal, No cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:** Clear, Smooth	Orthic A	Calcium carbonate at 750 mm
E	500	**Moisture status:** Dry; **Colour:** 10YR6/2; 8.9 % **clay;** **Mottles:** Few, Medium, Faint, Orange, Oxidized iron oxide; **Structure:** Weak, Single grain; **Consistence**: Loose, friable, non-sticky, Slightly plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:** Abrupt, smooth	E	
B	1200	**Moisture status:** Moist; **Colour:** 2.5YR4/2; 8.9 % **clay;** **Mottles:** Few, Medium, Faint, Orange, Oxidized iron oxide; **Structure:** Weak, Single grain; **Consistence**: Soft, Friable, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	Soft Plinthic B	

Profile No: DP3-01

27°04'06.05"S 32°28'21.04"E

Soil form:	Katspruit	**Soil family:**	
Described by:	LP	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Unknown

Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	400	**Moisture status:** Moist; **Colour:** 2.5Y2/1; 8.9 % **clay;** **Mottles:** Few, Medium, Faint, Orange, Oxidized iron oxide; **Structure:** Weak, Fine, Single grain; **Consistence**: Hard, Firm, Sticky, Plastic; **Pores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:** Gradual, Smooth	Orthic A	
G	1200	**Moisture status:** Moist; **Colour:** 10YR3/2; 8.9 % **clay;** **Mottles:** Many, Coarse, Prominent, Orange, Oxidized iron oxide; **Secondary mottles:** Few, Coarse, Prominent, Blue & Green, Oxidized iron oxide; **Structure:** Weak, Fine, Single grain; **Consistence**: Hard, Firm, Very sticky, Plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** Common, Lime concretions, Medium, Round; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	G	

Profile No: DP3-02

27°04'06.09"S 32°28'21.01"E

Soil form:	Katspruit	**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying materia**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	300	**Moisture status:** Dry; C**olour:** 2.5Y2/1; 8.9 % **clay;** M**ottles:** None; S**tructure:** Weak, Fine, Single grain; **Consistence**:Slightky hard, Firm, Sticky, Slightly plastic; P**ores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** Common, Lime concretions; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:** Gradual, Smooth	Orthic A	
G	1200	**Moisture status:** Dry; C**olour:** 10YR3/2; 8.9 % **clay;** M**ottles:** Few, Medium, Dinstinct, Yellow, Oxidized iron oxide; **Structure:** Weak, Fine, Single grain; **Consistence**: Soft, Slightly firm, Slightly sticky, Slightly plastic; P**ores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** Few, Lime concretions; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:**	G	

Profile No: DP3-03

27°04'07.04"S 32°28'20.05"E

Soil form:		**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Midslope	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Anthill mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	North-west	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying materia**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Unknown	**Vegetation/Land use:**	Grassveld, sparse
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	200	**Moisture status:** Dry; C**olour:** 10YR4/2; 8.9 % **clay;** M**ottles:** None; S**tructure:** Apedal, single grain; **Consistence**:Soft, Friable, Non-sticky, Non-plastic; P**ores & cracks:** Few, Normal, No cracks ; **Cementation:** none; **Lime:** **Slickensides:** none; **Cutans:** none; **Co-arse fragments:** Few, Lime concretions, Medium, Round; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** **Transition:**	Orthic A	

B	600	**Moisture status:** Dry; **Colour:** 10YR4/3; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Soft, Friable, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** **Slickensides:** none; **Cutans:** none; **Coarse fragments:** Many, Lime concretions, Medium, Round; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** **Transition:**	Yellow-brown apedal	
C	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Soft, Friable, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** **Slickensides:** none; **Cutans:** none; **Coarse fragments:** Very many, Lime concretions, Medium, Round; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** **Transition:**	Soft Carbonate	

Profile No: DP2-01

27°03'53.06"S 32°28'26.04"E

Soil form:	Katspruit	**Soil family:**	
Described by:	LP	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	0	**Microrelief:**	None
Slope shape:	Concave	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying materia**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	470	**Moisture status:** Dry; **Colour:** 10YR2/1; 8.9 % **clay;** **Mottles:** None; **Structure:** Moderate, Medium, Angular blocky; **Consistence:** Very hard, Firm, Non-sticky, Slightly plastic; **Pores & cracks:** Few, Normal, Fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 4s; **Roots:** Common; **Transition:** Clear, Tonguing;	Orthic A	The G is not very strongly structured; soft. Could be a Soft Plinthic B, i.e. Westleigh.

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
G	1200	**Moisture status:** Moist; **Colour:** 2.5Y3/1; 8.9 % **clay;** **Mottles:** Many, Coarse, Distinct, Yellow, Oxidized iron oxide; **Structure:** Apedal; **Consistence**: Soft, Friable, Non-sticky, Slightly plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 7s; **Roots:** Few; **Transition:**	G	

Profile No: DP2-02

27°03'53.06"S 32°28'25.06"E

Soil form:	Katspruit	**Soil family:**	
Described by:	LP	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Footslope	**Flood occurrence:**	Occasional
Slope: %	0	**Microrelief:**	None
Slope shape:	Concave	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying materia**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	104	**Moisture status:** Dry; **Colour:** 10YR2/1; 8.9 % **clay;** **Mottles:** None; **Structure:** Moderate, Medium, Subangular blocky; **Consistence:** Very hard, Very firm, Slightly-sticky, Non-plastic; **Pores & cracks:** Common, Normal, Fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** Few, Clay; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 4s; **Roots:** Few; **Transition:** Diffuse, Broken;	Orthic A	Very deep A-horizon
G	1200	**Moisture status:** Moist; **Colour:** 2.5Y3/1; 8.9 % **clay;** **Mottles:** Many, Coarse, Distinct, Yellow, Oxidized iron oxide; **Structure:** Apedal; **Consistence**: Soft, Slightly firm, Slightly-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 5s; **Roots:** None; **Transition:**	G	

Profile No: DP2-03

27°03'53.06"S 32°28'25.03"E

Soil form:	Kroonstad	**Soil family:**	

Described by:	LP	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Lower midslope	**Flood occurrence:**	Occasional
Slope: %	2	**Microrelief:**	None
Slope shape:	Concave	**Surface covering:**	None
Aspect:	East	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying materia**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	200	**Moisture status:** Dry; **Colour:** 10YR3/1; 8.9 % **clay;** **Mottles:** None; **Structure:** Moderate, Medium, Granular; **Consistence:** Hard, Slightly firm, Slightly-sticky, Non-plastic; **Pores & cracks:** Common, Normal, Very Coarse cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** None; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Common; **Transition:** Diffuse, Broken;	Orthic A	
E	800	**Moisture status:** Dry; **Colour:** 2.5Y5/1; 8.9 % **clay;** **Mottles:** Few, Fine, Faint, Yellow, brown & red, Unknown; **Structure:** Moderate, Medium, Prismatic; **Consistence:** Hard, Slightly firm, Slightly-sticky, Non-plastic; **Pores & cracks:** Common, Normal, Coarse cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** None; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 5s; **Roots:** Few; **Transition:** Clear, Tonguing;	E	
G	1200	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Many, Coarse, Prominent, Yellow, brown & red, Unknown; **Structure:** Moderate, Medium, Subangular blocky; **Consistence:** Slightly hard, Friable, Sticky, Slightly plastic; **Pores & cracks:** Common, Normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** Common, unknown; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 15s; **Roots:** None; **Transition:**	G	

Profile No: DP2-04

27°03'53.07"S 32°28'24.08"E

Soil form:	Montagu	**Soil family:**	
Described by:	LP	**Date described:**	06/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Upper midslope	**Flood occurrence:**	None

Slope: %	7		**Microrelief:**	Anthill mounds
Slope shape:	Convex		**Surface covering:**	None
Aspect:	East		**Surface rockiness:**	None
Wind erosion:	None		**Weathering of underlying materia**	Weak
Water erosion:	None		**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary:Aeolian&Alluv		**Vegetation/Land use:**	Grassveld, open
Underlying material:	Calcareous			

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	500	**Moisture status:** Dry; **Colour:** 10YR5/1; 8.9 % **clay;** **Mottles:** Many, Coarse, Distinct, Red and black, Oxidized iron oxide; **Structure:** Moderate, Medium, Subangular blocky; **Consistence:** Very hard, Very firm, Non-sticky, Non-plastic; **Pores & cracks:** Common, Normal,fine cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** Very many, Unknown; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 6s; **Roots:** Few; **Transition:** Clear, Smooth;	Orthic A	Local resident says this pan has been full beyond this point
B	700	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Weak, Medium, Crumb; **Consistence:** Slightly hard, Friable, Non-sticky, Non-plastic; **Pores & cracks:** Common, Normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** None; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Gradual, Tonguing;	Neocarbonate B	
C	1200	**Moisture status:** Dry; **Colour:** 2.5Y4/2; 8.9 % **clay;** **Mottles:** Many, Faint, Reddish brown, Illuvial iron; **Structure:** Moderate, Medium, Granular; **Consistence:** Hard, Firm, Sticky, Non-plastic; **Pores & cracks:** Common, Normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** Many, Unknown; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 5s; **Roots:** None; **Transition:**	Unspecified material with signs of wetness	

Profile No: DP2-05

27°03'53.09"S 32°28'24.00"E

Soil form:	Sepane		**Soil family:**	
Described by:	LP		**Date described:**	06/2012
Water table:	N/R		**Altitude:**	
Terrain unit:	Crest		**Flood occurrence:**	None
Slope: %	7		**Microrelief:**	Anthill mounds
Slope shape:	Convex		**Surface covering:**	None
Aspect:	East		**Surface rockiness:**	None

Wind erosion:	None	**Weathering of underlying materia**	Weak
Water erosion:	None	**Alteration of underlying material:**	FerruginisedCalcified?
Lithology of solum:	Binary:Aeolian&Alluv	**Vegetation/Land use:**	Grassveld, sparse
Underlying material:	Calcareous		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	250	**Moisture status:** Dry; C**olour:** 10YR4/1; 8.9 % **clay;** M**ottles:** Few, Medium, Faint, Gray and yellow, Reduced iron oxide; S**tructure:** Apedal, single grain; **Consistence:** Loose, Non-sticky, Non-plastic; P**ores & cracks:** Common, Normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** None; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Many; **Transition:** Abrupt, Smooth;	Orthic A	Local resident says this pan has been full beyond this point
B	700	**Moisture status:** Dry; C**olour:** 2.5Y5/2; 8.9 % **clay;** M**ottles:** Many, Coarse, Gray and yellow, Reduced iron oxide; S**tructure:** Strong, Coarse, Prismatic; **Consistence:** Very hard, Firm, Sticky, Non-plastic; P**ores & cracks:** Common, Normal, Medium cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** Many; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 5s; **Roots:** None; **Transition:** Diffuse, Broken;	Pedocutanic B	
C	1200	**Moisture status:** Dry; C**olour:** 2.5Y5/2; 8.9 % **clay;** M**ottles:** Few, Medium, Faint, Gray and yellow, Reduced iron oxide; S**tructure:** Apedal, single grain; **Consistence:** Soft, Friable, Sticky, Slightly-plastic; P**ores & cracks:** Common, Normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** None; **Coarse fragments:** None; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** None; **Transition:**	Unconsolidated material with signs of wetness	

Profile No: PL4-01

27°03'19.84"S 32°36'49.32"E

Soil form:	Champagne	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	1200	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	400	**Moisture status:** Moist; C**olour:** 10YR4/2; 8.9 % **clay;** M**ottles:** None; S**tructure:** weak, medium, granular; **Consistence**:slightly hard, slightly firm, slightly sticky, slightly plastic; P**ores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption: 3**s; **Roots:** common **Transition:** Clear, smooth	Organic O	Mottles at 500mm, but dissapear when soil becomes moist
C	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** M**ottles:** Few, fine, faint, red, oxidized iron oxide; S**tructure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption: 2**s; **Roots:** none; **Transition:**	Unspecified material with signs of wetness	

Profile No: PL4-02

27°03'19.20"S 32°36'49.56"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Footslope	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	350	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**: loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** few **Transition:** Clear, smooth	Orthic A	
E	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, faint, black, illuvial humus; **Mottles B**: few, fine, faint, red, oxidized iron oxide **Structure:** Apedal; single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E	

Profile No: PL4-03

27°03'18.65"S 32°36'49.94"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression crest	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	200	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Many; **Transition:** Clear, smooth	Orthic A	
E	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** None; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E	

Profile No: PL4-04

27°03'17.48"S 32°36'50.31"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	200	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption: 2**s; **Roots:** common **Transition:** Clear, smooth	Orthic A	

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
E	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** None; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption: 1**s; **Roots:** none; **Transition:**	E	

Profile No: PL3-01

27°03'13.01"S 32°37'49.06"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	1200	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	None
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	500	**Moisture status:** moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Common, fine, faint, red, Oxidized iron oxide; **Structure:** Apedal, single grain; **Consistence**:loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** few **Transition:** Abrupt, smooth	Orthic A	Clear sand at 60cm. At 1 m the mottles dissapear. Not saturated, but moist enough to be completely reduced.
E	1200	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Common, medium, distinct, red and yellow, oxidized iron oxide; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E	

Profile No: PL3-02			
Soil form:	Longlands	27°03'11.40"S 32°37'48.57"E	**Soil family:**
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	Anthill mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	250	**Moisture status:** moist; C**olour:** 10YR4/2; 8.9 % **clay;** M**ottles:** Few, fine, distinct, red, Oxidized iron oxide; S**tructure:** Apedal, single grain; **Consistence**:loose, friable, non-sticky, non-plastic; P**ores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** few **Transition:** Clear, smooth	Orthic A	A and E becomes grayer with depth. Mottles and moisture increase with depth
E	900	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** M**ottles:** Few, fine, distinct, red and yellow, oxidized iron oxide; S**tructure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** few; **Transition:** Gradual, smooth	E	
B	1200	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** M**ottles:** Common, medium, distinct, yellow, oxidized iron oxide; S**tructure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	Soft Plinthic B	

Profile No: PL3-03			
Soil form:	Fernwood	27°03'09.78"S 32°37'47.79"E	**Soil family:**

Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Anthill & earthworm mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	250	**Moisture status:** moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** Few, fine, distinct, red, Oxidized iron oxide; **Structure:** Apedal, single grain; **Consistence**:loose, friable, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** many; **Transition:** Clear, smooth	Orthic A	Mottles increase with depth. Mottles were not previously present in this profile, but now there are.
E	1200	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, distinct, red and yellow, oxidized iron oxide; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E	

Profile No: PL3-04

27°03'05.87"S 32°37'45.85"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Anthill mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open

Underlying material: Non-calcareous/acid

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	100	**Moisture status:** moist; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:loose, friable, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** few; **Transition:** Clear, smooth	Orthic A	Mottles are very sporadic but increases with depth
E1	900	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, faint, black, illuvial humus; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:** Clear, smooth	E	
E2	1200	**Moisture status:** Moist; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, faint, yellow and black, illuvial iron and humus; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E	

Profile No: PL5-01

27°02'23.15"S 32°39'17.63"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	Anthill & earthworm mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	190	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** M**ottles:** None; S**tructure:** Apedal, single grain; **Consistence**:loose, friable, non-sticky, non-plastic; P**ores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Common; **Transition:** Gradual, smooth	Orthic A	
E1	600	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** M**ottles:** Few, fine, distinct, yello, Oxidized iron oxide; S**tructure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Gradual, smooth	E	
E2	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** M**ottles:** None; S**tructure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E	

Profile No: PL5-02

27°02'22.25"S 32°39'19.19"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Anthill & earthworm mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	300	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:loose, friable, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** few; **Transition:** Gradual, smooth	Orthic A	A becomes grey when drying out. There is a thin bleached layer of sand at surface
E1	800	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** None; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:** Gradual, smooth	E	
E2	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, faint, red, oxidized iron oxide; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E	

Profile No: PL5-03

27°02'24.01"S 32°39'22.13"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Anthill & earthworm mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, sparse
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	100	**Moisture status:** Dry; **Colour:** 10YR4/2; 8.9 % **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:loose, friable, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:** Gradual, smooth	Orthic A
E1	700	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, faint; red and yellow, Oxidized iron oxide; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:** Gradual, smooth	E
E2	1200	**Moisture status:** Dry; **Colour:** 10YR5/4; 8.9 % **clay;** **Mottles:** Few, fine, faint; red and yellow, Oxidized iron oxide; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** none; **Transition:**	E

Profile No: PL6-01

27°03'31.67"S 32°35'23.18"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2012
Water table:	2000	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	Anthill & earthworm mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary,aeolian&alluv	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A1	50	**Moisture status:** Dry; **Colour:** 7.5YR3/1; 6% **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Loose, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 5s; **Roots:** Many; **Transition:** Clear, Smooth	Orthic A	Very thick root layer with abundant roots
A2	550	**Moisture status:** Dry; **Colour:** 7.5YR4/1; 6% **clay;** **Mottles:** None; **Structure:** apedal, single grain; **Consistence:** Loose, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Few; **Transition:** Gradual, Smooth	E	
E	1200	**Moisture status:** Moist; **Colour:** 7.5YR7/1; 3% **clay;** **Mottles:** Common, Coarse, Black, Illuvial humus; **Structure:** apedal, single grain; **Consistence:** Loose, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** None; **Transition:**	E	

Profile No: PL6-02

27°03'32.69"S 32°35'22.73"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2010
Water table:	2000	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	Anthill & earthworm mounds
Slope shape:	Convex	**Surface covering:**	None
Aspect:	North	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary,aeolian&alluv	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	750	**Moisture status:** Dry; **Colour:** 7.5YR3/1; 3% **clay;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Loose, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Many; **Transition:** Gradual, Smooth	Orthic A	
E	1200	**Moisture status:** Dry; **Colour:** 7.5YR4/1; 3% **clay;** **Mottles:** Many, Coarse, Black, Illuvial humus; **Structure:** apedal, single grain; **Consistence:** Loose, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:**	E	

Profile No: PL6-03

27°03'34.05"S 32°35'23.28"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	06/2010
Water table:	N/R	**Altitude:**	
Terrain unit:	Flat depression	**Flood occurrence:**	Occasional
Slope: %	N/A	**Microrelief:**	Anthill mounds
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Ferruginised
Lithology of solum:	Binary,aeolian&alluv	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	800	**Moisture status:** Dry; **Colour:** 7.5YR7/1; 3% **clay;** **Mottles:** None; **Structure:** Apedal, Single grain; **Consistence**:Loose, Non-sticky, Non-plastic; **Pores & cracks:** few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 3s; **Roots:** Many; **Transition:** Clear, Smooth	Orthic A	Fernwood if you classify up to 1200 mm, Longlands if you classify at a deeper depth

E	1200	**Moisture status:** Dry; **Colour:** 7.5YR7/1; 6% **clay;** M**ottles:** Common, Medium, Prominent, Black, Illuvial humus; S**tructure: A**pedal, Single grain; **Consistence:** Loose, Non-sticky, Non-plastic; P**ores & cracks:** few, normal, no cracks **Cementation:** none; **Lime:** none; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:**	E

Profile No: IDD3-01

26°56'59.47"S 32°49'12.51"E

Soil form:	Champagne	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	-50	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary, aeolian&alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	50	**Moisture status:** Wet; **Colour:** 10YR4/2; 10%, fine**;** **Mottles:** Many, fine, distinct, orange, oxidized iron oxide; **Structure:** Apedal, massive; **Consistence**:Soft, firm, slightly plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:** Gradual, smooth	Organic O	Blue-green tint. Chalk and sulphur smell present
C	1200	**Moisture status:** Wet; **Colour:** 10YR5/4; 3%, fine**;** **Mottles:** None; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	Unspecified material with signs of wetness	

Profile No: IDD3-02

26°56'59.35"S 32°49'12.63"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	-20	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary, aeolian&alluv	**Vegetation/Land use:**	Marsh

Underlying material:	Non-calcareous/acid

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	400	**Moisture status:** Wet; **Colour:** 10YR4/2; 10%, fine**;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Slightly hard, loose, slightly sticky, slightly plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:** Clear, smooth	Orthic A	This E horizon barely makes it as an E, but maybe E sepcifications are different in peat because this profile just barely missed being classed as a champagne
E	1200	**Moisture status:** Wet; **Colour:** 10YR5/4; 3%, fine**;** **Mottles:** None; **Structure:** apedal, single grain; **Consistence:** loose, non-sticky, non-plastic; **Pores & cracks:** Few, normal, no cracks **Cementation:** none; **Lime:** Slight; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	E	O horizon is shallower, and there is less water

Profile No: IDD3-03

26°56'59.44"S 32°49'13.29"E

Soil form:	Fernwood	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	700	**Altitude:**	
Terrain unit:	Footslope	**Flood occurrence:**	Occasional
Slope: %	10	**Microrelief:**	Dunes
Slope shape:	Concave	**Surface covering:**	None
Aspect:	West	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	200	**Moisture status:** Moist; **Colour:** 10YR4/2; 10%, fine**;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Slightly hard, firm, slightly sticky, slightly plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Common; **Transition:** Clear, smooth	Orthic A	Sulphuric smell at the bottom of the profile
E	450	**Moisture status:** Moist; **Colour:** 10YR5/4; 5%, fine**;** **Mottles:** None; **Structure:** apedal, single grain; **Consistence:** Soft, friable, non-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:** Clear, smooth	E	
C	1200	**Moisture status:** Wet; **Colour:** 10YR5/4; 3%, fine**;** **Mottles:** Few, Medium, Distinct, Yellow, Oxidized iron oxide; **Structure:** apedal, single grain; **Consistence: L**oose, non-sticky, non-plastic; **Pores & cracks:** Few, normal, no cracks **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** None; **Transition:**	Unspecified material with signs of wetness	

Profile No: IDD3-04

26°56'59.43"S 32°49'14.68"E

Soil form:	Namib	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Crest	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Convex	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	?	**Moisture status:** Dry; **Colour:** 10YR4/2; 3%, fine**;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Loose, non-sticky, non-lastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:**	Orthic A	Pieces of limestone (building material?) observed on site
C	1200	**Moisture status:** Dry; **Colour:** 10YR4/2; 3%, fine**;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Loose, non-sticky, non-lastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:**	Regic Sand	

Profile No: IDD5-01

26°56'53.11"S 32°48'54.81"E

Soil form:	Champagne	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	-600	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,aeolian&alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	1200	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Loose, non-sticky, slightly-plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:**	Organic O	Recent burn. Very wet.

Profile No: IDD5-02

Soil form:	Champagne	26°56'53.47"S 32°48'54.70"E	**Soil family:**	
Described by:	LP, CvH		**Date described:**	09/2012
Water table:	-20		**Altitude:**	
Terrain unit:	Closed depression		**Flood occurrence:**	Frequent
Slope: %	N/A		**Microrelief:**	Dunes
Slope shape:	Straight		**Surface covering:**	None
Aspect:	Level		**Surface rockiness:**	None
Wind erosion:	None		**Weathering of underlying material:**	Weak
Water erosion:	None		**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,aeolian&alluv		**Vegetation/Land use:**	Marsh
Underlying material:	Non-calcareous/acid			

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	1000	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Loose, slightly-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Many; **Transition:** Clear, smooth	Organic O	Recent burn. Very wet.
C	1200	**Moisture status:** Wet; **Colour:** 10YR5/4; 3%, fine**;** **Mottles:** None; **Structure:** **A**pedal, single grain; **Consistence:** :Loose, non-sticky, non-plastic; **Pores & cracks:** Few; normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:**	Uspecified material with signs of wetness	

Profile No: IDD5-03

Soil form:	Namib	26°56'53.65"S 32°48'54.44"E	**Soil family:**	
Described by:	LP, CvH		**Date described:**	09/2012
Water table:	N/R		**Altitude:**	
Terrain unit:	Lower midslope		**Flood occurrence:**	None
Slope: %	10		**Microrelief:**	Dunes
Slope shape:	Convex		**Surface covering:**	None
Aspect:	North		**Surface rockiness:**	None
Wind erosion:	None		**Weathering of underlying material:**	Weak
Water erosion:	None		**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian		**Vegetation/Land use:**	Grassveld, open

Underlying material:	Non-calcareous/acid

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	500	**Moisture status:** Moist; **Colour:** 10YR4/2; 10%, fine**;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Loose, non-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Few; **Transition:** Gradual; smooth	Orthic A	
C	1200	**Moisture status:** Moist; **Colour:** 10YR5/4; 5%, fine**;** **Mottles:** Few, medium, distinct, yellow, oxidized iron oxide; **Structure: A**pedal, single grain; **Consistence:** Loose, non-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** Many; **Transition:**	Regic Sand	

Profile No: IDD5-04

26°56'53.91"S 32°48'54.19"E

Soil form:	Namib	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Midslope	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Concave	**Surface covering:**	None
Aspect:	North	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, sparse
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks

A	700	**Moisture status:** Moist; **Colour:** 10YR4/2; 3%, fine**;** **Mottles:** None; **Structure:** Apedal, single grain; **Consistence**:Loose, non-sticky, non-plastic; **Pores & cracks:** Common, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Common; **Transition:** Gradual; smooth	Orthic A
C	1200	**Moisture status:** Moist; **Colour:** 10YR5/4; 3%, fine**;** **Mottles:** Few, medium, faint, yellow, oxidized iron oxide; **Structure: A**pedal, single grain; **Consistence:** Loose, non-sticky, non-plastic; **Pores & cracks:** Few, normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** None; **Transition:**	Regic Sand

Profile No: IDD2-01

26°56'41.95"S 32°49'03.28"E

Soil form:	Champagne	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	-200	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,aeolian&alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O	400	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Loose, non-sticky, slightly-plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:** Clear, smooth	Organic O	

O2	1200	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Loose, non-sticky, slightly-plastic; **Pores & cracks:** Few, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:**	Organic O	

Profile No: IDD2-02

26°56'41.51"S 32°49'03.14"E

Soil form:	Champagne	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	-150	**Altitude:**	
Terrain unit:	Closed depression	**Flood occurrence:**	Frequent
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Straight	**Surface covering:**	None
Aspect:	Level	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Binary,aeolian&alluv	**Vegetation/Land use:**	Marsh
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
O1	300	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Loose, slightly-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:** Diffuse, smooth	Organic O	O1 = fibrous; O2 = humified, C = sand
O2	1150	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Massive; **Consistence**:Loose, slightly-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:**	Organic O	

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
C	1200	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Single grain; **Consistence**:Loose, Non-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Many; **Transition:**	Regic sand	

Profile No: IDD2-03

26°56'40.71"S 32°49'02.62"E

Soil form:	Namib	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	400	**Altitude:**	
Terrain unit:	Footslope	**Flood occurrence:**	Occasional
Slope: %		**Microrelief:**	Dunes
Slope shape:	Concave	**Surface covering:**	None
Aspect:	South-east	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	200	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Single grain; **Consistence**: Soft, friable, slightly-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Many; **Transition:** Gradual, smooth	Orthic A	
C1	400	**Moisture status:** Moist; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Single grain; **Consistence**:Loose, slightly-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** Many; **Transition:** Clear, smooth	Regic sand	

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
C2	1200	**Moisture status:** Wet; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Single grain; **Consistence**:Loose, non-sticky, non-plastic; **Pores & cracks:** Common; normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** s; **Roots:** Few; **Transition:**	Regic sand	

Profile No: IDD2-04

26°56'40.19"S 32°49'02.15"E

Soil form:	Namib	**Soil family:**	
Described by:	LP, CvH	**Date described:**	09/2012
Water table:	N/R	**Altitude:**	
Terrain unit:	Crest	**Flood occurrence:**	None
Slope: %	N/A	**Microrelief:**	Dunes
Slope shape:	Concave	**Surface covering:**	None
Aspect:	South-east	**Surface rockiness:**	None
Wind erosion:	None	**Weathering of underlying material:**	Weak
Water erosion:	None	**Alteration of underlying material:**	Unknown
Lithology of solum:	Single, aeolian	**Vegetation/Land use:**	Grassveld, open
Underlying material:	Non-calcareous/acid		

Horizon	Depth(mm)	Description	Diagnostic horizons	Remarks
A	50	**Moisture status:** Dry; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** None; **Structure:** Apedal, Single grain; **Consistence**: Loose, non-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks ; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 1s; **Roots:** **Transition:**	Orthic A	
C	1200	**Moisture status:** Dry; **Colour:** 10YR4/2; 12%, fine**;** **Mottles:** Few, Coarse, Distinct, Grey & white, reduced iron oxide **Structure:** Apedal, Single grain; **Consistence**:Loose, non-sticky, non-plastic; **Pores & cracks:** Many, normal, no cracks; **Cementation:** none; **Lime:** None; **Slickensides:** none; **Cutans:** none; **Coarse fragments:** none; **Features:** none; **Stratification:** none; **Water absorption:** 2s; **Roots:** **Transition:** Clear, smooth	Regic sand	

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
IDD 5-01				**Champagne**														
IDD	5	1	50	211050	12557.8	3.92	0.14	0.79	0.77	28.01	4.66	1947.5	14.75	880	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
IDD	5	1	100	230625	11076.6	5.15	0.05	3.62	1.53	96.78	4.66	1485.0	11.25	830	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
IDD	5	1	150	153450	8880.7	3.78	0.04	2.96	1.24	23.71	4.60	1215.0	8.25	940	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
IDD	5	1	200	110288	5326.8	2.81	0.03	2.45	1.02	20.99	4.60	1017.5	7.00	990	2.5Y 3/1	2.5Y 2.5/1	86.57	11.67
IDD	5	1	250	108338	4201.9	3.12	0.05	2.30	1.43	26.42	4.53	1147.5	6.50	960	10YR 3/1	2.5Y 2.5/1	93.40	6.67
IDD	5	1	300	124050	3851.9	2.34	0.05	2.45	1.25	29.25	4.54	945.0	5.25	960	10YR 3/1	2.5Y 2.5/1	95.20	6.67
IDD	5	1	400	79538	3322.7	1.15	0.04	1.28	0.72	17.18	4.53	329.8	3.50	1540	10YR 3/1	2.5Y 2.5/1	90.00	8.33
IDD	5	1	500	61050	2430.0	0.67	0.04	0.92	0.65	25.99	4.55	297.0	2.50	1400	2.5Y 3/1	2.5Y 2.5/1	94.64	6.67
IDD	5	1	600	92363	4490.8	2.50	0.09	2.52	1.33	29.03	4.53	406.3	5.00	9400	2.5Y 2.5/1	2.5Y 2.5/1	0.00	0.00
IDD	5	1	900	88650	3592.9	0.58	0.04	0.71	0.50	15.22	4.44	341.0	3.25	1020	10YR 3/1	2.5Y 2.5/1	95.35	5.00
IDD	5	1	1200	56730	2995.1	1.18	0.05	0.79	0.52	10.33	9.58	244.3	2.50	1520	2.5Y 3/1	2.5Y 2.5/1	95.17	5.00
IDD 5-02				**Champagne**														
IDD	5	2	50	227925	13920.0	5.48	0.93	3.13	1.96	81.56	4.02	1112.5	0.75	1160	10YR 3/2	10YR 2/1	0.00	0.00
IDD	5	2	100	237825	12902.2	4.96	0.29	3.46	1.26	93.52	4.07	1202.5	14.00	9800	7.5YR 3/2	10YR 2/1	0.00	0.00
IDD	5	2	150	145425	9590.4	2.95	0.11	2.24	0.73	18.49	4.22	905.0	6.00	1440	7.5YR 3/2	10YR 2/1	0.00	0.00
IDD	5	2	200	72375	3403.1	1.68	0.06	1.09	0.30	17.18	4.46	755.0	2.25	1840	2.5Y 3/1	10YR 2/1	84.50	13.33
IDD	5	2	270	47153	3043.4	0.69	0.04	0.41	0.17	9.03	4.85	296.8	1.50	2060	2.5Y 3/1	10YR 2/1	90.53	6.67
IDD	5	2	370	22733	530.3	0.35	0.01	0.25	0.16	3.91	4.95	127.3	1.25	3500	2.5Y 4/1	10YR 2/1	95.87	1.67
IDD	5	2	470	10286	406.1	0.47	0.02	0.35	0.13	3.04	5.14	71.5	1.25	5700	2.5Y 4/1	10YR 2/1	96.53	1.67
IDD	5	2	570	8273	273.8	0.42	0.01	0.33	0.12	3.04	5.23	74.0	1.00	4850	2.5Y 4/1	2.5Y 3/1	92.80	6.67
IDD	5	2	660	4410	254.5	0.59	0.02	0.46	0.12	1.96	5.20	74.3	1.00	5350	2.5Y 5/2	2.5Y 3/2	96.63	5.00
IDD	5	2	860	4995	180.7	0.35	0.02	0.28	0.12	1.85	5.21	53.8	0.75	5000	2.5Y 5/3	10YR 3/2	92.27	6.67
IDD	5	2	1000	1610	804.1	0.35	0.03	0.26	0.18	1.52	4.98	72.5	0.75	5100	10YR 6/2	2.5Y 4/3	98.30	1.67
IDD 5-03				**Namib**														
IDD	5	3	50	19118	1219.6	2.54	0.11	0.81	0.11	5.44	5.27	119.8	30.50	2340	10YR 3/1	10YR 2/1	97.60	3.33
IDD	5	3	100	18720	768.2	1.61	0.07	0.67	0.13	3.37	5.32	89.3	4.75	4400	10YR 4/1	10YR 2/1	97.60	3.33
IDD	5	3	150	9135	638.2	1.30	0.06	0.53	0.10	3.91	5.06	48.5	3.25	7200	10YR 5/1	10YR 2/1	96.33	3.33
IDD	5	3	220	3930	341.8	0.58	0.03	0.30	0.04	1.30	5.10	24.0	2.50	10100	10YR 5/1	10YR 3/1	97.47	3.33
IDD	5	3	250														92.87	6.67
IDD	5	3	320	2738	318.8	0.64	0.04	0.30	0.09	2.28	5.66	17.3	2.25	14900	10YR 5/1	10YR 3/1	95.84	3.33
IDD	5	3	420	2333	264.2	0.37	0.03	0.18	0.05	0.98	5.07	18.3	2.25	8500	10YR 5/2	10YR 3/1	99.70	1.67
IDD	5	3	530	1718	163.1	0.41	0.05	0.26	0.09	1.52	4.46	20.3	2.50	3400	10YR 6/2	10YR 3/1	96.87	3.33
IDD	5	3	680	1110	165.9	0.31	0.03	0.23	0.04	1.52	5.46	17.3	2.50	21600	10YR 6/2	10YR 4/2	100.17	1.67
IDD	5	3	830	2430	99.0	0.33	0.02	0.25	0.05	0.98	5.55	11.5	2.50	32000	10YR 6/2	10YR 4/2	100.23	1.67
IDD	5	3	1100	0	76.5	0.23	0.02	0.20	0.04	0.98	5.71	16.5	2.25	22600	10YR 6/2	10YR 4/3	95.77	5.00
IDD 5-04				**Namib**														

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
IDD	5	4	50	10868	600.1	2.46	0.25	0.87	0.17	3.48	6.33	247.5	57.00	2020	2.5Y 4/1	10YR 2/1	96.41	5.00
IDD	5	4	100	6293	511.5	0.92	0.06	0.44	0.10	3.15	5.98	198.5	23.25	5300	2.5Y 4/1	10YR 2/1	98.77	1.67
IDD	5	4	150	5258	364.4	1.07	0.07	0.54	0.15	2.07	5.94	200.0	17.75	5800	10YR 4/1	10YR 2/1	95.03	4.00
IDD	5	4	200	4065	353.3	0.76	0.05	0.53	0.18	2.72	5.89	214.8	10.25	8700	10YR 4/2	10YR 2/1	100.20	1.67
IDD	5	4	250	3555	261.1	0.58	0.04	0.43	0.12	3.15	5.84	161.0	6.75	9900	10YR 4/2	10YR 2/2	99.30	1.67
IDD	5	4	300	3225	279.8	0.70	0.05	0.41	0.10	2.39	5.92	116.3	3.25	10400	10YR 4/2	10YR 2/2	98.50	0.67
IDD	5	4	370	2865	247.0	0.44	0.03	0.33	0.09	1.85	6.04	109.5	2.50	10200	10YR 4/2	10YR 2/2	100.13	1.67
IDD	5	4	520	3075	312.4	0.10	0.02	0.10	0.09	1.63	5.81	161.0	9.00	16600	10YR 5/2	10YR 2/2	99.07	1.67
IDD	5	4	670	2378	256.9	0.35	0.03	0.25	0.12	2.07	5.84	101.0	3.50	18200	2.5Y 5/2	2.5Y 3/2	94.13	5.00
IDD	5	4	920	1928	179.3	0.45	0.03	0.33	0.10	1.52	5.88	67.8	1.50	13800	10YR 4/3	2.5Y 3/2	97.67	3.33
IDD	5	4	1170	1325	168.1	0.42	0.04	0.33	0.10	1.74	5.74	45.5	0.75	11000	10YR 5/3	10YR 3/3	93.77	6.67
IDD 3-01				**Champagne**														
IDD	3	1	50	59880	4069.2	27.45	0.52	7.41	1.82	24.79	6.44	5525.0	89.25	330	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
IDD	3	1	100	102675	5685.1	35.83	0.18	7.90	3.83	22.18	6.29	4300.0	26.75	274	2.5Y 3/2	2.5Y 2.5/1	0.00	0.00
IDD	3	1	150	157950	7472.9	32.53	0.14	7.41	4.18	43.50	5.70	5850.0	18.75	310	10YR 2/1	2.5Y 2.5/1	0.00	0.00
IDD	3	1	200	162900	6661.2	21.26	0.07	4.94	2.72	28.27	5.46	1592.5	3.00	351	10YR 2/1	10YR 2/1	0.00	0.00
IDD	3	1	250	82393	4069.1	16.97	0.05	4.44	1.88	27.19	5.15	1435.0	3.25	465	10YR 2/1	10YR 2/1	0.00	0.00
IDD	3	1	300	96638	3154.6	11.38	0.04	3.29	1.43	20.88	5.28	737.5	1.50	315	10YR 2/1	10YR 2/1	0.00	0.00
IDD	3	1	400	51720	1074.5	4.71	0.03	1.37	0.88	16.75	4.58	190.3	1.75	500	2.5Y 2.5/1	10YR 2/1	0.00	0.00
IDD	3	1	500	12585	171.8	1.42	0.02	0.41	0.28	5.87	4.47	57.8	1.00	650	10YR 4/1	10YR 2/2	0.00	0.00
IDD	3	1	600	12930	207.9	1.12	0.02	0.41	0.29	3.81	4.36	52.3	0.75	920	2.5Y 3/1	10YR 2/2	0.00	0.00
IDD	3	1	900	11438	419.5	0.95	0.02	0.40	0.23	6.63	4.42	50.3	0.75	1390	2.5Y 4/1	10YR 2/2	0.00	0.00
IDD	3	1	1200	7050	283.3	0.87	0.02	0.33	0.19	5.44	4.69	34.5	1.00	2100	10YR 5/2	10YR 3/2	0.00	0.00
IDD 3-02				**Fernwood**														
IDD	3	2	50	73525	5079.6	12.87	0.32	2.47	1.44	31.32	5.45	3752.5	17.75	625	10YR 3/1	10YR 2/1	0.00	0.00
IDD	3	2	100	55410	3050.2	10.68	0.13	3.46	1.14	25.34	4.73	2757.5	4.50	580	10YR 3/1	10YR 2/1	0.00	0.00
IDD	3	2	150	24780	1393.5	3.54	0.02	1.02	0.45	8.26	4.65	812.5	1.75	990	10YR 3/1	10YR 2/1	0.00	0.00
IDD	3	2	200	24894	1528.7	1.92	0.02	0.59	0.37	11.64	4.38	266.3	1.50	1140	10YR 4/1	10YR 2/1	0.00	0.00
IDD	3	2	250	50145	2544.8	2.32	0.02	0.95	0.54	18.92	4.29	339.5	1.75	1100	10YR 3/1	10YR 2/1	0.00	0.00
IDD	3	2	300	65288	3056.4	2.08	0.02	0.97	0.59	19.03	4.20	1.3	2.00	980	10YR 2/1	10YR 2/1	0.00	0.00
IDD	3	2	400	47700	698.2	1.46	0.01	0.76	0.43	17.62	4.24	193.5	2.00	1200	10YR 2/1	10YR 2/1	0.00	0.00
IDD	3	2	500	31590	1275.6	1.26	0.01	0.74	0.30	16.20	4.56	124.3	1.50	1840	10YR 3/1	10YR 2/1	0.00	0.00
IDD	3	2	600	20588	6352.5	1.19	0.01	0.56	0.21	10.44	4.70	70.0	1.25	2380	10YR 3/1	10YR 2/1	0.00	0.00
IDD	3	2	900	3395	195.8	0.96	0.01	0.25	0.18	0.54	4.94	27.5	0.75	3800	10YR 6/2	10YR 3/2	0.00	0.00
IDD	3	2	1200	2985	200.6	0.91	0.01	0.21	0.21	3.26	5.08	32.3	1.00	4150	10YR 6/2	10YR 3/2	0.00	0.00
IDD 3-03				**Fernwood**														
IDD	3	3	50	6675	365.5	1.44	0.07	0.40	0.10	2.39	5.81	206.0	39.25	9650	10YR 5/2	5Y 3/2	0.00	0.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
IDD	3	3	100	21698	357.6	0.89	0.06	0.30	0.12	2.07	5.33	185.3	13.25	14000	10YR 5/2	5Y 3/2	0.00	0.00
IDD	3	3	150	4770	291.9	0.59	0.04	0.23	0.08	3.70	5.16	174.5	6.25	17000	10YR 5/2	2.5Y 4/2	0.00	0.00
IDD	3	3	200	4410	344.1	0.57	0.03	0.23	0.07	2.17	5.17	192.8	4.25	18400	10YR 5/2	2.5Y 4/2	0.00	0.00
IDD	3	3	250	4425	204.1	0.27	0.04	0.16	0.08	1.30	5.20	169.8	3.25	23200	10YR 5/2	2.5Y 4/2	0.00	0.00
IDD	3	3	300	2370	207.2	0.46	0.03	0.18	0.07	1.20	5.08	159.5	2.75	24200	10YR 5/2	2.5Y 4/2	0.00	0.00
IDD	3	3	400	3225	200.6	0.27	0.01	0.15	0.03	1.41	4.92	151.5	2.00	21200	10YR 6/2	2.5Y 4/2	0.00	0.00
IDD	3	3	500	2535	204.1	0.39	0.03	0.16	0.07	1.52	5.04	152.0	2.00	27400	10YR 6/2	2.5Y 4/2	0.00	0.00
IDD	3	3	600	2858	193.4	0.23	0.02	0.13	0.03	1.41	5.14	165.8	1.75	32900	10YR 6/2	2.5Y 4/2	0.00	0.00
IDD	3	3	900	1960	0.6	0.28	0.02	0.12	0.04	1.41	5.30	128.0	2.50	35500	10YR 6/3	2.5Y 4/2	0.00	0.00
IDD	3	3	1200	2750	160.3	0.20	0.02	0.02	0.03	1.30	5.85	135.0	2.25	33500	10YR 5/3	2.5Y 4/2	0.00	0.00
IDD 3-04				**Namib**														
IDD	3	4	50	8940	567.1	3.02	0.12	0.67	0.11	3.40	5.52	336.3	34.50	3700	2.5Y 4/2	2.5Y 3/1	0.00	0.00
IDD	3	4	100	6150	484.6	1.63	0.09	0.41	0.10	2.14	5.54	273.8	4.50	9100	2.5Y 5/2	2.5Y 3/2	0.00	0.00
IDD	3	4	150	4305	319.0	0.94	0.06	0.33	0.08	1.61	5.31	251.5	1.50	12400	2.5Y 5/2	2.5Y 3/2	0.00	0.00
IDD	3	4	200	4613	247.9	0.74	0.05	0.26	0.08	1.54	5.14	249.5	1.00	12400	10YR 6/2	2.5Y 3/3	0.00	0.00
IDD	3	4	250	3615	235.2	0.99	0.05	0.26	0.10	1.28	5.10	246.0	0.75	14200	10YR 6/2	2.5Y 3/3	0.00	0.00
IDD	3	4	300	3650	235.5	0.85	0.04	0.21	0.06	1.45	4.93	260.5	0.75	15200	10YR 6/2	10YR 4/2	0.00	0.00
IDD	3	4	400	3080	179.3	0.57	0.03	0.16	0.05	1.37	5.01	276.3	0.25	18600	10YR 6/3	10YR 4/2	0.00	0.00
IDD	3	4	500	3315	199.8	0.64	0.04	0.16	0.05	1.10	5.05	322.3	0.25	24200	10YR 6/3	10YR 4/2	0.00	0.00
IDD	3	4	600	2730	148.8	0.58	0.03	0.13	0.05	0.69	4.68	346.5	0.25	18000	10YR 6/3	10YR 4/2	0.00	0.00
IDD	3	4	900	2710	137.8	0.69	0.04	0.16	0.05	1.14	5.34	344.8	0.50	20200	10YR 6/3	10YR 4/3	0.00	0.00
IDD	3	4	1200	1715	81.3	0.51	0.03	0.16	0.07	0.59	5.41	331.0	0.50	12400	10YR 6/4	10YR 4/3	0.00	0.00
IDD 2-01				**Champagne**														
IDD	2	1	50	205200	10130.0	3.26	0.19	2.17	1.01	55.46	4.00	2362.5	7.00	1260	2.5Y 2.5/1	10YR 2/1	0.00	0.00
IDD	2	1	100	198750	10339.7	1.60	0.11	1.66	0.97	54.37	4.20	1950.0	5.00	1340	2.5Y 2.5/1	10YR 2/1	0.00	0.00
IDD	2	1	150	233250	9485.0	1.39	0.12	1.86	1.03	46.76	4.09	1415.0	2.00	1420	2.5Y 2.5/1	10YR 2/1	0.00	0.00
IDD	2	1	200	175200	7228.2	0.90	0.04	0.35	0.34	24.58	4.33	1137.5	1.75	1500	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	1	250	139425	4970.3	1.01	0.02	0.48	0.32	22.18	4.49	1097.5	2.00	1760	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	1	300	121388	6543.0	1.23	0.03	0.77	0.40	22.29	4.48	977.5	1.75	1680	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	1	400	131850	12457.2	1.14	0.04	0.67	0.51	22.84	4.46	1502.5	2.00	1600	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	1	500	113700	9271.9	1.18	0.02	0.56	0.40	17.29	4.46	1132.5	2.00	1440	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	1	600	105750	8559.0	1.14	0.03	0.51	0.28	17.62	4.44	1145.0	1.50	1460	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	1	900	95738	4525.5	1.22	0.03	0.40	0.30	11.31	4.59	647.5	1.50	1600	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	1	1200	59663	1865.6	1.01	0.02	0.12	0.10	4.13	4.55	235.0	1.00	1920	10YR 2/1	10YR 2/1	0.00	0.00
IDD 2-02				**Champagne**														
IDD	2	2	50	222450	13474.3	0.45	0.31	1.32	2.25	58.72	4.23	1787.5	4.75	700	2.5Y 3/1	10YR 2/1	0.00	0.00
IDD	2	2	100	214275	12359.0	0.38	0.12	1.58	1.49	48.93	4.35	399.0	2.00	1120	2.5Y 3/1	10YR 2/1	0.00	0.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
IDD	2	2	150	230925	9729.1	13.44	0.09	1.96	1.25	51.11	4.64	284.5	2.50	1080	2.5Y 3/1	10YR 2/1	0.00	0.00
IDD	2	2	200	178425	9219.0	1.57	0.07	2.09	1.44	53.28	4.81	374.0	4.50	1420	10YR 3/1	10YR 2/1	0.00	0.00
IDD	2	2	250	219075	9708.1	1.12	0.05	1.45	1.19	35.67	4.72	245.3	2.50	1540	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	2	300	219675	10053.4	1.00	0.06	1.74	1.47	54.37	4.77	309.0	3.25	1250	2.5Y 3/1	10YR 2/1	0.00	0.00
IDD	2	2	400	167850	8105.1	1.85	0.04	1.86	1.18	33.49	4.82	261.3	3.00	1320	10YR 3/1	10YR 2/1	0.00	0.00
IDD	2	2	500	43770	2140.8	1.19	0.02	1.05	0.43	14.68	4.93	93.0	1.75	1760	10YR 3/1	10YR 2/1	0.00	0.00
IDD	2	2	700	36165	885.7	1.38	0.02	0.76	0.31	10.55	5.00	60.5	1.50	2400	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	2	900	16125	721.8	1.35	0.02	0.67	0.25	8.81	4.89	59.5	1.50	2180	10YR 3/1	10YR 2/1	0.00	0.00
IDD	2	2	1200														0.00	0.00
IDD 2-03				**Namib**														
IDD	2	3	50	56580	2199.7	1.03	0.13	0.72	0.33	17.92	4.69	394.3	6.50	1580	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	3	100	51720	3097.8	0.89	0.10	0.64	0.33	11.05	4.58	395.5	4.25	1300	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	3	150	45510	2028.3	0.56	0.11	0.61	0.39	10.18	4.63	224.3	2.75	1430	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	3	200	11963	1512.9	0.47	0.05	0.36	0.28	12.44	4.48	157.0	2.00	1520	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	3	250	17380	904.7	0.60	0.04	0.21	0.21	7.57	4.59	123.3	1.00	2660	10YR 2/1	10YR 2/1	0.00	0.00
IDD	2	3	300	12450	626.4	0.69	0.03	0.16	0.17	4.96	4.59	81.5	1.00	3340	10YR 3/1	10YR 2/1	0.00	0.00
IDD	2	3	400	9900	560.3	3.58	0.11	0.69	0.61	5.65	4.53	76.8	0.75	4000	10YR 3/1	10YR 2/1	0.00	0.00
IDD	2	3	500	5880	280.3	0.21	0.02	0.03	0.05	4.52	4.60	55.8	0.75	5100	10YR 4/2	10YR 2/2	0.00	0.00
IDD	2	3	600	3060	206.6	0.95	0.03	0.13	0.21	5.65	4.57	25.5	1.00	6950	10YR 5/3	2.5Y 3/3	0.00	0.00
IDD	2	3	900	1695	187.8	0.66	0.02	0.10	0.14	2.09	4.75	22.3	1.00	7500	2.5Y 6/3	2.5Y 3/2	0.00	0.00
IDD	2	3	1200	1440	143.5	0.78	0.04	0.15	0.16	2.70	5.14	16.8	1.25	6150	2.5Y 6/3	2.5Y 3/3	0.00	0.00
IDD 2-04				**Namib**														
IDD	2	4	50	10770	769.7	2.43	0.08	0.81	0.08	3.15	6.27	258.3	70.25	7090	2.5Y 5/1	2.5Y 3/2	0.00	0.00
IDD	2	4	100	8835	365.8	1.59	0.06	0.53	0.06	2.61	5.40	188.8	23.25	7100	2.5Y 6/2	2.5Y 3/2	0.00	0.00
IDD	2	4	150	4095	310.2	1.15	0.04	0.38	0.05	1.85	5.15	184.3	10.50	8700	10YR 6/2	10YR 3/2	0.00	0.00
IDD	2	4	200	5858	182.4	0.98	0.03	0.36	0.09	2.07	5.14	181.0	5.50	10900	10YR 6/2	10YR 3/2	0.00	0.00
IDD	2	4	250	4418	237.3	1.09	0.04	0.35	0.07	1.85	5.00	168.5	5.50	13400	10YR 6/2	10YR 3/2	0.00	0.00
IDD	2	4	300	4553	274.8	0.88	0.03	0.31	0.04	2.28	5.10	151.8	7.75	12600	10YR 6/2	10YR 3/2	0.00	0.00
IDD	2	4	400	4155	187.4	0.85	0.03	0.25	0.04	1.09	5.46	147.5	4.25	16000	10YR 6/2	10YR 3/2	0.00	0.00
IDD	2	4	500	3555	202.5	0.81	0.03	0.20	0.05	1.74	5.05	163.3	2.00	26000	10YR 6/2	10YR 3/3	0.00	0.00
IDD	2	4	600	4365	140.7	0.82	0.03	0.23	0.06	1.20	5.04	157.5	2.00	22400	10YR 6/2	10YR 3/3	0.00	0.00
IDD	2	4	900	1845	131.5	0.80	0.03	0.18	0.10	0.87	5.03	175.8	2.00	19500	10YR 6/2	10YR 3/3	0.00	0.00
IDD	2	4	1200	1465	132.0	0.22	0.03	0.13	0.04	1.30	5.16	215.3	2.00	2300	10YR 6/3	10YR 3/3	0.00	0.00
MS 6-01				**Champagne**														
MS	6	1	50	119775	8665.8	35.63	1.63	10.53	15.92	56.55	7.80	4800.0	212.25	60	5Y 3/1	10YR 2/1	0.00	0.00
MS	6	1	100	137288	7996.1	61.48	1.53	13.99	16.44	64.16	7.71	7000.0	238.00	62	5Y 3/1	10YR 2/1	0.00	0.00
MS	6	1	150	156000	7947.8	41.92	1.19	11.69	13.66	69.60	7.63	8125.0	232.00	55.2	5Y 3/1	10YR 2/1	0.00	0.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
MS	6	1	200	156750	9531.9	68.56	1.82	17.45	19.49	80.47	7.74	6550.0	227.00	63	5Y 3/1	10YR 2/1	0.00	0.00
MS	6	1	250	181350	10346.7	64.57	1.85	18.11	22.36	89.17	7.71	10175.0	236.75	56	2.5Y 3/1	10YR 2/1	0.00	0.00
MS	6	1	300	230925	13384.0	57.68	1.59	14.98	21.23	81.56	7.64	11775.0	202.50	53	2.5Y 3/1	10YR 2/1	0.00	0.00
MS	6	1	400	234300	14221.9	83.33	1.39	21.23	25.23	17.40	7.57	14000.0	233.00	54	2.5Y 2.5/1	10YR 2/1	0.00	0.00
MS	6	1	500	210075	11193.6	114.47	1.13	22.55	25.92	94.61	7.57	5600.0	233.50	65	2.5Y 2.5/1	10YR 2/1	0.00	0.00
MS	6	1	600	191025	9740.2	91.22	0.90	19.75	20.01	83.73	7.62	13250.0	167.50	66	2.5Y 2.5/1	10YR 2/1	0.00	0.00
MS	6	1	900	209850	12064.8	55.39	0.35	8.40	11.14	83.73	6.88	13050.0	115.00	130	10YR 2/1	10YR 2/1	0.00	0.00
MS	6	1	1200	199050	8327.2	68.56	0.20	13.50	9.48	51.11	5.33	8250.0	85.00	142	10YR 2/1	10YR 2/1	0.00	0.00
MS 6-02				**Champagne**														
MS	6	2	50	173625	12961.2	24.95	0.79	4.77	4.70	56.55	7.59	7325.0	245.00	168	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	100	209700	10572.5	44.31	0.96	7.24	5.83	54.37	7.58	8500.0	187.50	154	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	150	175275	9969.4	44.41	0.78	7.57	6.79	81.56	7.68	8775.0	202.50	162	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	200	211400	11628.4	65.17	0.80	10.53	8.44	79.38	7.37	9700.0	187.50	130	2.5Y 2.5/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	250	204200	12684.7	52.79	0.80	10.53	8.70	90.26	7.49	8275.0	217.50	140	2.5Y 2.5/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	300	253500	13827.1	66.77	0.77	12.84	9.83	90.26	7.49	14375.0	172.50	126	2.5Y 2.5/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	400	194100	13531.7	37.33	0.38	8.89	8.00	89.17	7.12	8000.0	165.75	121	10YR 2/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	500	174650	12296.9	38.42	0.45	8.72	8.96	67.42	7.23	8350.0	150.25	133	10YR 2/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	600	244200	11995.9	70.96	0.49	10.53	10.70	60.90	6.30	13275.0	171.50	157	10YR 2/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	900	208014	13815.2	59.58	0.36	8.56	10.09	86.99	4.35	16250.0	123.50	182	10YR 2/1	2.5Y 2.5/1	0.00	0.00
MS	6	2	1200	217700	11141.2	71.46	0.11	10.37	6.96	54.37	4.74	19050.0	166.75	148	10YR 2/1	2.5Y 2.5/1	0.00	0.00
MS 6-03				**Fernwood**														
MS	6	3	50	57915	3888.6	59.18	1.45	18.11	0.90	53.28	8.32	3257.5	95.75	630	2.5Y 2.5/1	10YR 2/1	0.00	0.00
MS	6	3	100	63400	3136.8	45.21	1.31	14.32	1.26	32.95	8.51	2997.5	88.50	714	2.5Y 2.5/1	10YR 2/1	0.00	0.00
MS	6	3	150	44970	2821.6	36.93	1.31	13.50	2.19	29.25	8.77	3162.5	70.50	580	2.5Y 2.5/1	10YR 2/1	0.00	0.00
MS	6	3	200	34410	1791.1	34.43	1.06	15.80	3.91	27.62	9.00	2795.0	63.50	480	2.5Y 2.5/1	2.5Y 2.5/1	0.00	0.00
MS	6	3	250	16470	900.8	25.85	0.58	8.07	3.31	17.51	9.44	2430.0	54.25	510	2.5Y 4/1	2.5Y 3/1	0.00	0.00
MS	6	3	300	11903	621.8	23.15	0.50	6.58	2.87	8.05	9.60	2267.5	58.00	530	2.5Y 4/1	2.5Y 3/2	0.00	0.00
MS	6	3	400	6885	380.3	18.56	0.19	4.77	1.56	5.55	9.64	1877.5	57.00	830	2.5Y 5/2	5Y 3/2	0.00	0.00
MS	6	3	500	9165	149.9	20.56	0.16	4.94	1.96	5.98	9.80	2455.0	64.50	740	2.5Y 4/3	5Y 4/3	0.00	0.00
MS	6	3	600	2055	101.2	15.82	0.11	3.46	1.64	4.35	9.91	2122.5	66.25	840	2.5Y 4/3	5Y 4/3	0.00	0.00
MS	6	3	900	4395	51.6	3.91	0.03	1.09	0.37	1.20	9.78	895.0	7.25	1980	2.5Y 7/2	2.5Y 5/3	0.00	0.00
MS	6	3	1200	2310	47.2	2.35	0.05	0.91	0.53	1.41	9.53	790.0	2.75	1150	2.5Y 6/3	2.5Y 5/4	0.00	0.00
MS 6-04				**Brandvlei**														
MS	6	5	50	3780	457.4	3.84	0.22	1.07	0.29	2.94	7.35	1020.0	56.50	2840	2.5Y 5/3	10YR 2/2	0.00	0.00
MS	6	5	100	2730	396.1	2.84	0.12	0.95	0.10	2.28	7.58	1435.0	66.50	4250	2.5Y 5/3	10YR 3/2	0.00	0.00
MS	6	5	150	2850	334.9	2.33	0.15	0.97	0.07	1.96	7.48	1175.0	55.25	5900	2.5Y 5/3	10YR 3/3	0.00	0.00
MS	6	5	200	4238	214.0	2.27	0.11	0.81	0.23	2.07	7.66	1065.0	37.00	7500	10YR 6/3	10YR 3/3	0.00	0.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
MS	6	5	250	4830	231.3	3.12	0.13	0.74	0.27	1.85	8.79	905.0	38.50	6100	10YR 6/3	10YR 4/3	0.00	0.00
MS	6	5	300	2460	2.5	8.27	0.10	0.84	0.23	3.37	8.78	1102.5	49.50	6100	10YR 5/3	10YR 4/3	0.00	0.00
MS	6	5	400	2093	97.6	11.75	0.09	1.02	0.26	3.59	8.93	975.0	100.00	6200	10YR 5/4	10YR 3/4	0.00	0.00
MS	6	5	500	1755	147.4	8.96	0.07	0.92	0.23	2.07	8.81	1947.5	127.00	6700	10YR 5/4	10YR 3/4	0.00	0.00
MS	6	5	600	2565	112.5	6.26	0.08	0.58	0.25	1.41	8.86	2097.5	58.00	7300	2.5Y 5/4	10YR 3/4	0.00	0.00
MS	6	5	900	735	62.7	4.78	0.05	0.49	0.10	1.85	8.78	1802.5	35.50	8500	2.5Y 5/4	10YR 3/4	0.00	0.00
MS	6	5	1200	1170	73.0	13.47	0.06	1.00	0.07	6.42	8.71	2425.0	80.50	3150	2.5Y 5/4	2.5Y 4/4	0.00	0.00
MS 1-01				**Champagne**														
MS	1	1	50	114450	6589.3	80.14	1.18	14.32	11.31	44.58	7.86	3677.5	121.75	125	2.5Y 3/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	100	114675	4460.5	43.31	0.65	10.53	9.48	31.21	8.06	3215.0	45.25	130	2.5Y 4/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	150	102900	4272.2	62.97	0.53	15.14	14.01	30.99	8.07	3685.0	65.00	142	2.5Y 4/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	200	54240	3013.6	36.83	0.47	6.75	7.92	23.81	8.10	2662.5	68.75	142	2.5Y 4/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	250	55290	2187.0	35.83	0.42	6.26	8.53	22.07	8.09	2220.0	61.25	103	2.5Y 5/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	300	45090	2395.1	44.91	0.32	6.58	9.13	21.75	8.08	2487.5	89.50	122	2.5Y 5/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	400	32355	1217.9	28.04	0.28	3.46	5.74	14.68	8.14	102.5	84.50	124	2.5Y 5/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	500	12285	416.5	24.85	0.12	2.26	2.20	6.63	8.29	965.0	61.50	205	2.5Y 5/1	2.5Y 2.5/1	0.00	0.00
MS	1	1	600	5820	224.2	13.36	0.17	1.98	1.63	2.72	8.01	847.5	7.25	222	2.5Y 4/1	10YR 3/1	0.00	0.00
MS	1	1	900	3533	168.9	8.47	0.26	2.02	2.06	4.02	8.06	702.5	5.50	218	2.5Y 4/1	2.5Y 3/2	0.00	0.00
MS	1	1	1200	3338	54.1	12.99	0.52	4.28	4.18	11.31	7.77	957.5	6.00	164	2.5Y 4/1	2.5Y 3/2	0.00	0.00
MS 1-02				**Champagne**														
MS	1	2	50	129788	8540.0	61.58	1.95	9.55	8.35	39.15	7.74	7950.0	172.00	88	10YR 4/1	10YR 2/1	0.00	0.00
MS	1	2	100	155700	9403.9	78.24	1.58	13.66	12.18	40.02	7.85	13200.0	108.25	97	10YR 4/1	10YR 2/1	0.00	0.00
MS	1	2	150	129863	5708.6	101.40	1.37	20.74	14.01	49.59	7.94	11025.0	102.75	90	2.5Y 3/1	10YR 2/1	0.00	0.00
MS	1	2	200	102950	4410.0	55.19	1.27	7.24	6.70	30.45	7.97	7950.0	74.25	113	2.5Y 4/1	10YR 2/1	0.00	0.00
MS	1	2	250	104580	4294.0	94.91	0.71	13.17	9.74	60.03	7.93	10375.0	66.50	126	2.5Y 4/1	10YR 2/1	0.00	0.00
MS	1	2	300	101820	4522.8	67.86	0.70	9.05	8.61	36.54	7.82	8950.0	77.50	124	2.5Y 4/1	10YR 2/1	0.00	0.00
MS	1	2	400	118590	4894.6	71.86	0.83	10.04	7.48	49.59	7.77	9850.0	70.25	116	2.5Y 4/1	10YR 2/1	0.00	0.00
MS	1	2	500	197175	8520.9	89.72	0.83	14.16	10.27	44.37	7.65	15675.0	64.75	126	2.5Y 3/1	10YR 2/1	0.00	0.00
MS	1	2	600	151950	962.0	68.66	0.54	7.74	6.18	33.93	7.71	11425.0	70.50	128	10YR 4/1	10YR 2/1	0.00	0.00
MS	1	2	900	170775	6990.4	134.03	0.49	13.66	10.87	26.62	7.74	18375.0	72.00	108	10YR 3/1	10YR 2/1	0.00	0.00
MS	1	2	1200	93150	2964.5	61.88	0.19	5.76	4.00	28.10	7.55	2820.0	92.00	216	2.5Y 6/1	2.5Y 2.5/1	0.00	0.00
MS 1-03				**Westleigh**														
MS	1	3	50	76950	3962.2	71.26	1.46	10.37	0.37	75.03	8.20	3815.0	90.75	940	10YR 2/1	10YR 2/1	0.00	0.00
MS	1	3	100	48255	3021.8	71.56	1.11	13.50	0.53	20.55	8.45	6425.0	58.00	880	10YR 3/1	10YR 2/1	0.00	0.00
MS	1	3	150	38970	2373.1	41.02	0.66	8.72	0.50	20.23	8.61	4072.5	50.50	890	2.5Y 3/1	10YR 2/1	0.00	0.00
MS	1	3	200	32010	1697.0	25.25	0.50	5.10	0.65	18.27	8.77	7075.0	55.00	1080	2.5Y 4/1	10YR 2/1	0.00	0.00
MS	1	3	250	32010	1224.7	27.54	0.46	5.60	0.97	5.87	9.16	7000.0	61.75	900	2.5Y 4/1	10YR 2/1	0.00	0.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
MS	1	3	300	20550	842.6	40.42	0.37	8.72	1.64	14.57	9.17	24350.0	126.25	840	2.5Y 4/2	10YR 2/2	0.00	0.00
MS	1	3	400	15960	670.8	45.21	0.30	8.89	1.01	9.24	8.87	22975.0	95.50	1040	2.5Y 5/2	10YR 2/2	0.00	0.00
MS	1	3	500	4710	67.7	2.44	0.07	0.77	0.24	1.61	9.20	1160.0	9.00	3050	2.5Y 6/3	2.5Y 3/3	0.00	0.00
MS	1	3	600	1920	35.7	4.52	0.12	1.71	0.56	3.24	9.33	1120.0	9.25	1700	2.5Y 5/3	2.5Y 4/3	0.00	0.00
MS	1	3	900	1883	67.2	5.55	0.16	2.53	0.95	100.04	8.77	8300.0	33.75	560	2.5Y 5/4	2.5Y 4/3	0.00	0.00
MS	1	3	1200	2955	82.4	9.90	0.30	4.77	1.89	7.94	8.16	207500.0	88.50	282	2.5Y 5/6	10YR 4/4	0.00	0.00
MS 1-04				**Longlands**														
MS	1	4	50	23213	1921.1	29.94	0.26	5.93	0.10	28.49	8.41	870.0	92.50	1540	2.5Y 3/1	10YR 2/1	0.00	0.00
MS	1	4	100	17678	1483.2	27.84	0.21	7.08	0.11	22.62	8.48	408.3	57.00	1660	2.5Y 3/2	2.5Y 2.5/1	0.00	0.00
MS	1	4	150	5138	567.4	12.05	0.10	4.28	0.10	21.64	8.68	388.0	46.75	2660	2.5Y 5/2	2.5Y 3/2	0.00	0.00
MS	1	4	200	1965	306.0	23.45	0.13	5.76	0.36	23.27	8.85	391.3	42.50	3250	2.5Y 6/3	2.5Y 5/3	0.00	0.00
MS	1	4	250	2498	205.4	14.88	0.09	4.28	0.20	23.05	8.97	782.5	37.00	3050	2.5Y 6/2	2.5Y 4/3	0.00	0.00
MS	1	4	300	210	173.3	18.06	0.13	5.43	0.13	41.32	8.98	1305.0	37.75	2650	2.5Y 5/2	2.5Y 4/3	0.00	0.00
MS	1	4	400	172	122.3	26.35	0.16	5.27	0.10	7.94	8.88	2247.5	76.25	2120	2.5Y 6/4	2.5Y 4/4	0.00	0.00
MS	1	4	500	575	104.0	35.63	0.10	5.10	0.11	25.01	9.05	1727.5	116.25	2380	2.5Y 7/4	2.5Y 6/4	0.00	0.00
MS	1	4	600	1755	69.7	21.36	0.15	3.95	0.15	17.40	8.92	3185.0	160.00	2130	10YR 6/6	2.5Y 5/6	0.00	0.00
MS	1	4	900	1305	65.1	8.43	0.12	2.60	0.17	29.03	8.84	2997.5	42.75	1980	10YR 6/8	2.5Y 5/6	0.00	0.00
MS	1	4	1200	90	72.1	4.72	0.25	5.60	1.11	20.44	8.69	2475.0	35.75	440	10YR 5/8	2.5Y 5/6	0.00	0.00
MS 4-01				**Champagne**														
MS	4	1	50	203100	13767.8	100.70	2.42	17.45	13.40	85.91	7.56	12750.0	193.25	102	2.5Y 2.5/1	2.5Y 2/1	0.00	0.00
MS	4	1	100	247200	14085.5	144.01	2.15	19.59	14.44	98.96	7.50	11200.0	145.50	104	2.5Y 2.5/1	2.5Y 2/1	0.00	0.00
MS	4	1	150	233475	13968.7	131.74	1.75	25.68	19.31	104.39	7.23	12400.0	135.75	90	2.5Y 2.5/1	2.5Y 2/1	0.00	0.00
MS	4	1	200	253350	12064.7	142.32	1.18	18.77	15.05	90.26	5.77	13475.0	91.75	89	10YR 2/1	2.5Y 2/1	0.00	0.00
MS	4	1	250	233850	12467.2	197.60	0.97	18.44	15.14	94.61	5.04	10825.0	63.00	97	10YR 2/1	2.5Y 2/1	0.00	0.00
MS	4	1	300	270450	13776.9	87.92	0.83	7.74	7.31	78.29	4.87	11500.0	56.50	116	2.5Y 2.5/1	2.5Y 2/1	0.00	0.00
MS	4	1	400	225900	11892.5	110.78	0.41	6.09	6.35	85.91	4.16	10225.0	24.75	132	2.5Y 2.5/1	2.5Y 2/1	0.00	0.00
MS	4	1	500	244950	11905.8	139.02	0.46	8.23	7.74	105.48	4.54	9575.0	33.00	164	5Y 2.5/1	2.5Y 2/1	0.00	0.00
MS	4	1	600	228675	11084.0	92.91	0.33	7.57	4.78	80.47	5.52	9025.0	39.50	240	5Y 2.5/1	2.5Y 2/1	0.00	0.00
MS	4	1	900	117900	10943.3	72.16	0.14	4.77	1.64	50.02	7.46	3535.0	47.75	264	5Y 4/1	2.5Y 2/1	0.00	0.00
MS	4	1	1200	13965	803.7	26.25	0.15	1.37	0.41	4.89	7.21	972.5	9.00	390	5Y 5/1	5Y 2.5/1	82.93	16.67
MS 4-02				**Champagne**														
MS	4	2	50	84225	12960.0	98.80	0.88	11.85	11.40	145.72	8.04	7225.0	240.25	142	2.5Y 4/1	2.5Y 2.5/1	66.03	32.50
MS	4	2	100	83213	5326.2	100.30	0.70	10.21	10.87	101.13	8.01	8400.0	178.25	154	2.5Y 4/1	2.5Y 2.5/1	57.53	40.00
MS	4	2	150	108225	5260.0	106.59	0.54	11.03	12.70	166.38	7.98	6925.0	163.25	149	2.5Y 4/1	2.5Y 2.5/1	58.90	40.00
MS	4	2	200	111360	5920.3	114.37	0.73	14.32	15.22	147.89	7.94	8175.0	117.00	149	5Y 3/1	2.5Y 2.5/1	58.74	38.33
MS	4	2	250	131775	5225.0	117.76	0.68	15.31	16.88	54.37	7.85	8950.0	117.75	144	5Y 4/1	2.5Y 2.5/1	58.32	40.00
MS	4	2	300	113898	5469.3	113.87	0.60	13.50	15.83	141.37	7.90	8175.0	118.50	142	5Y 3/1	2.5Y 2.5/1	55.30	43.33

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
MS	4	2	400	153150	6352.5	100.40	0.57	12.35	14.53	162.03	7.90	7775.0	130.75	140	5Y 3/1	2.5Y 2.5/1	0.00	0.00
MS	4	2	500	93413	3566.7	96.41	0.42	9.71	12.09	41.32	7.96	7400.0	140.00	182	2.5Y 4/1	2.5Y 2.5/1	65.92	31.67
MS	4	2	600	118650	5213.3	107.98	0.40	10.21	12.53	22.84	7.86	8400.0	130.50	182	2.5Y 4/1	2.5Y 2.5/1	0.00	0.00
MS	4	2	900	104963	3380.6	87.33	0.33	7.74	9.40	16.42	7.84	5475.0	122.50	196	2.5Y 5/1	2.5Y 2.5/1	0.00	0.00
MS	4	2	1200	78113	2095.8	69.76	0.29	5.60	6.52	24.68	7.89	2955.0	86.25	204	5Y 6/1	5Y 2.5/1	67.43	33.33
MS 4-03			**Removed**															
MS	4	3	50	95625	7674.8	72.46	1.87	16.46	18.79	35.89	7.74	3785.0	113.00	124	2.5Y 3/1	2.5Y 2.5/1	62.24	36.80
MS	4	3	100	99638	6052.8	65.47	0.94	12.51	15.57	41.32	7.93	2152.5	107.00	122	2.5Y 3/1	2.5Y 2.5/1	74.25	25.00
MS	4	3	150	89400	5742.5	38.82	0.29	5.60	5.48	35.89	7.96	3500.0	106.50	120	2.5Y 4/1	2.5Y 2.5/1	70.68	30.00
MS	4	3	200	62250	4094.7	72.75	0.76	15.14	25.58	34.80	8.04	3050.0	86.75	124	2.5Y 4/1	2.5Y 2.5/1	78.17	22.50
MS	4	3	250	55575	473.1	73.35	0.69	13.99	26.71	31.54	7.99	2997.5	78.75	106	2.5Y 4/1	2.5Y 2.5/1	73.20	26.67
MS	4	3	300	50835	724.8	69.76	0.62	12.84	26.27	17.73	8.01	3852.5	74.50	110	5Y 5/1	2.5Y 2.5/1	75.32	25.00
MS	4	3	400	45580	2208.1	65.87	0.54	9.88	22.44	19.57	8.09	555.0	75.00	112	5Y 5/1	2.5Y 2.5/1	76.00	23.33
MS	4	3	500	42420	2077.7	59.78	0.43	8.07	15.83	26.10	8.13	815.0	86.25	118	5Y 5/1	2.5Y 2.5/1	76.93	23.33
MS	4	3	600	25928	1195.5	54.99	0.26	5.76	11.83	12.94	8.11	3107.5	84.25	122	2.5Y 8/2	2.5Y 3/2	71.23	26.67
MS	4	3	900	13560	699.0	38.82	0.16	2.58	5.57	13.48	8.11	3642.5	66.00	206	2.5Y 7/2	2.5Y 5/3	72.31	25.00
MS	4	3	1200	18025	803.0	56.39	0.18	4.44	8.70	10.44	8.17	2880.0	52.75	186	2.5Y 8/1	2.5Y 4/2	65.85	35.00
MS 4-04				**Westleigh**														
MS	4	4	50	89250	5750.2	72.85	1.96	13.83	0.39	33.71	8.02	2577.5	105.50	690	2.5Y 2.5/1	10YR 2/1	55.35	45.00
MS	4	4	100	72300	3941.5	48.00	1.02	9.71	0.42	56.55	8.10	2647.5	85.50	840	2.5Y 2.5/1	10YR 2/1	49.93	47.50
MS	4	4	150	54195	3056.5	53.89	1.18	11.69	0.41	15.22	8.24	2577.5	67.50	760	2.5Y 3/1	2.5Y 2.5/1	64.00	35.00
MS	4	4	200	32040	2054.0	31.74	0.78	7.74	0.53	32.84	8.36	1825.0	41.00	715	2.5Y 4/1	2.5Y 2.5/1	62.25	35.00
MS	4	4	250	24780	1926.9	28.94	1.19	7.08	1.10	13.05	8.47	1767.5	36.75	590	2.5Y 4/1	2.5Y 2.5/1	63.70	35.00
MS	4	4	300	20415	1004.8	26.95	1.06	6.42	1.49	22.51	8.64	2230.0	44.50	550	2.5Y 4/1	2.5Y 2.5/1	65.40	32.50
MS	4	4	400	16125	803.5	33.33	0.76	8.23	1.62	18.49	8.84	3382.5	53.50	605	2.5Y 4/2	2.5Y 2.5/1	67.84	32.00
MS	4	4	500	5018	280.7	26.65	0.21	4.12	0.78	8.81	9.01	3700.0	53.00	730	2.5Y 5/2	2.5Y 3/3	81.27	18.33
MS	4	4	600	1613	93.4	16.47	0.11	2.63	0.42	4.78	8.96	1787.5	29.75	1480	2.5Y 7/2	2.5Y 4/3	77.60	23.33
MS	4	4	900	1733	170.0	14.57	0.30	2.47	1.19	8.37	8.85	3902.5	15.25	455	10YR 4/4	2.5Y 4/4	69.93	30.00
MS	4	4	1200	3810	293.8	0.53	0.32	1.15	1.44	7.94	8.60	8850.0	26.50	340	10YR 3/4	10YR 3/3	71.88	28.80
MS 4-05				**Brandvlei**														
MS	4	5	50	50145	3872.8	32.53	1.08	7.24	0.27	32.62	8.28	1615.0	184.25	1010	10YR 2/1	10YR 2/1	71.33	26.67
MS	4	5	100	34350	2560.8	24.35	0.78	4.77	0.25	17.18	8.13	1382.5	127.25	1000	10YR 2/1	10YR 2/1	72.70	25.00
MS	4	5	150	21450	1936.6	17.17	0.69	3.46	0.25	23.05	8.43	1150.0	103.25	1220	2.5Y 2.5/1	10YR 2/1	77.80	22.50
MS	4	5	200	15480	1196.0	26.75	0.56	7.74	0.27	13.38	9.02	1037.5	79.25	1240	2.5Y 4/1	2.5Y 2.5/1	79.05	20.00
MS	4	5	250	16830	829.6	26.15	0.44	8.23	0.49	9.79	8.80	1022.5	44.25	1160	2.5Y 6/1	2.5Y 6/2	65.76	32.80
MS	4	5	300	7208	463.3	27.45	0.41	7.24	0.50	6.31	9.07	1420.0	34.50	980	2.5Y 7/1	2.5Y 6/2	63.00	36.00
MS	4	5	400	3890	295.2	21.46	0.36	4.94	0.54	4.89	9.22	1427.5	25.00	980	2.5Y 7/2	2.5Y 6/2	69.60	30.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
MS	4	5	500	1900	183.9	27.35	0.54	6.26	1.13	5.76	9.50	2510.0	43.75	950	2.5Y 7/3	2.5Y 5/3	83.92	16.00
MS	4	5	600	1823	124.2	23.25	0.58	5.76	1.73	8.92	9.47	2375.0	70.25	800	2.5Y 6/3	2.5Y 5/3	83.04	16.00
MS	4	5	900	1620	139.1	21.26	0.65	6.09	4.87	7.50	9.06	767.5	146.50	410	2.5Y 5/4	10YR 4/4	83.92	18.00
MS	4	5	1200	765	125.0	15.87	0.65	4.28	2.61	10.55	8.78	1447.5	120.50	252	10YR 4/6	10YR 4/4	77.53	22.00
PP 1-01				**?**														
PP	1	1	50	18675	1986.0	8.95	1.52	4.44	17.31	10.33	6.22	2540.0	99.00	198	2.5Y 4/1	2.5Y 2.5Y/1	51.32	45.92
PP	1	1	100	12435	1324.5	6.46	1.07	6.91	7.05	9.24	6.67	2440.0	105.50	345	2.5Y 4/1	2.5Y 2.5Y/1	76.44	24.32
PP	1	1	150	3818	439.9	4.76	0.79	5.93	5.74	0.22	7.57	2272.5	156.50	360	2.5Y 4/1	2.5Y 3/1	75.08	22.52
PP	1	1	200	4905	435.8	4.48	0.82	5.60	6.26	10.11	7.42	2110.0	160.00	319	2.5Y 5/1	2.5Y 3/1	65.56	31.92
PP	1	1	250	4710	360.4	4.04	0.74	4.94	6.44	8.70	7.65	1990.0	150.00	320	2.5Y 5/1	2.5Y 3/1	81.60	17.52
PP	1	1	300	4283	311.8	3.55	0.73	4.94	6.18	6.31	7.78	1947.5	167.25	258	2.5Y 5/1	2.5Y 3/1	80.20	18.32
PP	1	1	400	3428	235.5	2.55	0.53	5.10	6.44	3.26	8.04	1592.5	111.00	302	2.5Y 5/1	2.5Y 3/1	77.24	21.32
PP	1	1	500	3270	157.6	2.88	0.54	3.79	5.57	7.39	8.86	1985.0	65.50	204	2.5Y 6/1	2.5Y 4/1	72.80	24.32
PP	1	1	600	3195	146.3	2.42	0.55	5.27	8.18	10.11	8.29	2725.0	73.00	214	2.5Y 6/2	2.5Y 4/2	82.40	22.12
PP	1	1	900	1995	108.5	1.75	0.47	4.12	7.39	8.70	8.56	1385.0	55.75	254	2.5Y 6/3	2.5Y 5/2	76.44	22.32
PP	1	1	1200	2558	111.7	1.66	0.47	3.79	6.70	6.96	8.70	795.0	37.50	168	2.5Y 7/1	2.5Y 5/2	83.84	17.72
PP 1-02				**Katspruit**														
PP	1	2	50	29078	2221.8	7.73	1.23	5.10	18.01	19.90	6.07	1482.5	96.75	580	2.5Y 4/1	2.5Y 2.5Y/1	69.08	29.56
PP	1	2	100	25650	1836.8	6.42	1.06	5.76	5.22	10.77	6.20	1302.5	83.75	770	2.5Y 4/1	2.5Y 2.5Y/1	75.16	25.76
PP	1	2	150	18600	1522.8	5.55	0.95	6.42	5.74	12.40	6.65	1280.0	79.75	770	2.5Y 4/1	2.5Y 2.5Y/1	71.00	26.40
PP	1	2	200	4733	564.9	3.68	0.76	5.76	5.65	11.31	7.00	2270.0	84.25	515	2.5Y 4/1	2.5Y 2.5Y/1	74.28	25.16
PP	1	2	250	2850	367.5	3.28	0.70	4.77	5.92	12.29	7.28	2350.0	155.50	410	2.5Y 4/1	2.5Y 3/1	83.88	13.40
PP	1	2	300	1688	246.7	3.05	0.76	5.10	6.52	11.85	7.67	2512.5	238.25	370	2.5Y 5/1	2.5Y 3/1	76.60	21.96
PP	1	2	400	1463	201.9	2.73	0.78	5.76	7.57	10.22	7.62	2930.0	246.00	286	2.5Y 6/1	2.5Y 3/1	66.36	31.76
PP	1	2	500	525	87.7	1.90	0.59	5.76	9.05	7.83	8.50	3072.5	157.00	365	2.5Y 7/1	2.5Y 4/1	79.96	17.00
PP	1	2	600	210	70.4	1.41	0.47	5.27	8.87	8.16	8.41	1387.5	113.50	360	2.5Y 6/2	2.5Y 5/2	71.52	27.00
PP	1	2	900	75	60.4	3.60	0.41	4.77	8.70	6.85	9.05	371.5	85.75	380	2.5Y 6/3	2.5Y 5/2	82.64	15.40
PP	1	2	1200	0	52.3	1.26	0.42	4.94	9.57	0.87	8.73	289.0	86.50	242	2.5Y 6/3	2.5Y 5/2	72.52	24.76
PP 1-03				**Sterkspruit**														
PP	1	3	50	6683	325.6	1.90	0.13	0.77	0.36	5.33	7.10	387.8	24.25	2300	7.5YR 5/1	2.5Y 3/1	87.28	12.40
PP	1	3	100	4110	409.5	2.14	0.16	1.76	1.70	8.59	6.93	1052.5	30.50	590	10YR 5/1	2.5Y 2.5Y/1	87.00	9.80
PP	1	3	150	7748	540.5	3.97	0.36	1.32	6.18	12.51	7.27	980.0	97.25	410	2.5Y 4/1	2.5Y 2.5Y/1	85.28	16.20
PP	1	3	200	3743	366.2	3.15	0.36	1.64	7.39	14.03	8.06	1035.0	129.00	280	2.5Y 4/1	2.5Y 2.5Y/1	80.84	18.40
PP	1	3	250	2048	280.6	3.23	0.47	1.64	8.70	13.59	8.80	1130.0	123.50	280	2.5YR 5/1	2.5Y 3/1	78.24	23.00
PP	1	3	300	1830	194.5	2.55	0.42	1.48	7.13	9.90	8.66	1172.5	113.50	214	2.5YR 5/1	2.5Y 3/1	78.44	22.40
PP	1	3	400	750	165.9	2.31	0.47	1.97	11.40	12.29	8.96	1215.0	213.75	188	2.5YR 5/1	2.5Y 4/1	74.80	26.80
PP	1	3	500	502	125.0	1.59	0.49	1.48	11.57	10.11	8.83	1205.0	187.75	160	2.5YR 5/1	2.5Y 4/1	71.96	28.60

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
PP	1	3	600	120	114.3	1.79	0.47	1.81	14.18	15.01	9.02	1487.5	208.25	152	10YR 5/2	2.5Y 3/2	77.80	24.40
PP	1	3	900	230	78.4	1.00	0.29	1.15	8.70	14.03	8.93	1580.0	243.00	152	2.5Y 6/2	2.5Y 4/2	68.64	31.00
PP	1	3	1200	230	50.0	1.21	0.28	1.15	9.92	15.12	9.34	955.0	205.00	146	2.5Y 6/3	2.5Y 4/2	75.04	26.60
PP 2-01				**Sterkspruit**														
PP	2	1	50	17033	1264.2	7.59	1.05	5.93	1.30	18.38	6.00	1647.5	61.25	770	10YR 4/1	10YR 2/1	75.88	22.56
PP	2	1	100	10508	956.0	5.12	0.61	3.46	1.05	9.46	5.88	1490.0	54.00	770	10YR 4/1	10YR 2/1	81.96	15.40
PP	2	1	150	8363	859.9	5.34	0.57	3.95	1.41	10.22	5.80	1590.0	46.25	655	10YR 4/1	10YR 2/1	81.84	15.56
PP	2	1	200	8820	529.9	5.34	0.57	4.77	1.95	15.12	5.87	1592.5	40.50	700	2.5Y 3/1	10YR 2/1	79.76	17.36
PP	2	1	250	7403	24.1	4.69	0.47	4.94	2.11	9.79	6.09	1740.0	27.50	495	2.5Y 3/1	10YR 2/1	80.64	16.16
PP	2	1	300	6225	284.1	4.87	0.49	4.61	2.77	12.51	6.54	2055.0	27.00	375	2.5Y 3/1	10YR 2/2	84.48	16.36
PP	2	1	400	2933	331.4	3.50	0.32	3.79	2.64	8.81	7.12	1047.5	16.00	460	2.5Y 3/2	10YR 2/2	84.44	14.00
PP	2	1	500	2430	321.8	1.92	0.16	1.88	1.73	10.33	7.63	1190.0	19.25	213	2.5Y 4/1	2.5Y 4/1	77.16	21.16
PP	2	1	600	1980	209.8	2.24	0.57	4.12	8.53	12.29	8.12	1125.0	52.00	196	2.5Y 4/1	2.5Y 4/1	75.08	22.80
PP	2	1	900	855	97.8	1.96	0.54	5.76	8.96	11.09	8.45	1050.0	202.50	180	2.5Y 5/2	2.5Y 5/2	78.80	18.56
PP	2	1	1200	330	75.4	1.90	0.47	6.26	10.79	15.55	8.83	882.5	585.00	149	2.5Y 6/3	2.5Y 6/2	78.52	18.56
PP 2-02				**Sterkspruit**														
PP	2	2	50	18413	1053.4	2.57	0.68	2.30	1.24	10.77	5.76	1442.5	91.00	780	10YR 4/1	10YR 2/1	86.00	13.40
PP	2	2	100	8573	721.0	1.29	0.32	2.32	0.90	10.77	5.76	1157.5	58.25	900	10YR 3/1	10YR 2/1	85.80	11.20
PP	2	2	150	6743	518.2	1.09	0.30	0.99	1.71	16.42	6.32	1180.0	21.50	725	10YR 4/2	10YR 2/1	85.00	12.20
PP	2	2	200	7845	588.5	0.93	0.30	1.15	2.00	11.09	6.49	1362.5	39.25	535	2.5Y 3/2	10YR 2/1	82.92	14.20
PP	2	2	250	6270	516.6	1.09	0.31	0.82	2.37	15.55	6.71	1290.0	33.25	510	2.5Y 3/2	10YR 3/1	82.08	15.00
PP	2	2	300	5040	348.9	1.72	0.40	0.82	3.74	20.23	7.16	1460.0	32.75	345	10YR 3/2	10YR 3/1	82.64	14.40
PP	2	2	400	3720	286.6	1.00	0.34	1.15	5.13	14.68	8.02	970.0	61.50	320	10YR 4/1	10YR 3/1	83.80	12.72
PP	2	2	500	3030	182.0	1.11	0.43	1.32	6.44	13.92	8.06	707.5	33.75	256	10YR 4/1	10YR 4/1	79.72	17.52
PP	2	2	600	2708	163.9	1.28	0.48	0.99	6.18	15.99	8.32	1045.0	41.25	220	10YR 4/2	2.5Y 4/2	73.40	24.20
PP	2	2	900	2250	107.8	1.27	0.52	1.48	9.31	20.88	8.43	940.0	110.75	210	10YR 4/2	2.5Y 4/2	78.88	18.52
PP	2	2	1200	2460	80.7	2.53	0.35	1.32	8.87	18.16	8.55	732.5	330.00	168	2.5Y 6/3	2.5Y 5/2	78.28	18.72
PP 2-03				**Sterkspruit**														
PP	2	3	50	7178	570.6	3.09	0.32	1.38	0.42	5.87	6.06	351.0	41.00	4050	2.5Y 5/2	2.5Y 2.5Y/1	89.72	7.70
PP	2	3	100	5235	510.6	2.53	0.23	2.02	0.94	4.13	6.31	1355.0	26.75	4150	2.5Y 4/2	2.5Y 3/2	93.68	5.30
PP	2	3	150	4695	497.2	3.01	0.25	2.96	1.86	6.42	5.97	2590.0	41.25	1860	10YR 5/3	2.5Y 3/3	83.32	15.10
PP	2	3	200	5115	483.9	3.57	0.27	4.44	4.87	11.42	6.45	2722.5	88.00	1000	10YR 5/3	2.5Y 3/3	81.76	16.30
PP	2	3	250	3780	389.9	3.90	0.29	3.95	5.31	12.51	6.87	1862.5	128.25	680	2.5Y 5/2	2.5Y 4/2	87.96	10.30
PP	2	3	300	3240	295.5	4.29	0.32	5.76	6.52	10.11	7.28	1275.0	245.25	620	2.5Y 5/2	2.5Y 4/2	74.36	24.30
PP	2	3	400	3165	224.4	3.85	0.31	5.27	6.96	12.18	7.72	372.3	202.25	390	2.5Y 5/2	2.5Y 4/2	72.32	25.10
PP	2	3	500	2520	254.0	3.63	0.29	5.76	8.44	10.00	7.83	266.5	104.75	286	2.5Y 5/2	2.5Y 4/2	78.52	19.90
PP	2	3	600	2865	207.5	3.07	0.33	4.77	8.70	9.35	8.21	213.0	78.00	214	2.5Y 5/2	2.5Y 4/2	80.88	18.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
PP	2	3	900	1895	126.8	3.31	0.41	6.58	12.96	11.09	8.75	266.5	171.75	170	2.5Y 5/2	2.5Y 5/2	67.60	30.40
PP	2	3	1200	1430	133.5	5.81	0.37	3.79	8.61	12.40	8.98	290.0	507.50	140	2.5Y 5/3	2.5Y 5/2	77.40	22.80
PP 3-01				**Katspruit**														
PP	3	1	50	24338	1879.7	12.31	1.37	4.12	1.91	20.66	6.47	1915.0	68.50	248	2.5Y 3/1	10YR 2/1	74.40	22.80
PP	3	1	100	24960	2354.9	16.46	1.91	2.14	1.22	13.48	6.07	2285.0	74.75	235	2.5Y 3/1	10YR 2/1	64.00	33.80
PP	3	1	150	20483	1807.4	7.68	1.40	5.27	3.74	14.03	6.07	1877.5	62.50	186	2.5Y 3/1	10YR 2/1	74.36	23.40
PP	3	1	200	18923	1732.1	6.78	1.37	5.27	4.00	23.81	6.12	2045.0	67.50	180	2.5Y 3/1	10YR 2/1	76.84	22.20
PP	3	1	250	17243	1432.3	7.11	1.67	4.44	19.49	19.46	6.23	1645.0	56.00	162	2.5Y 3/1	10YR 2/1	70.56	26.40
PP	3	1	300	5460	623.1	4.27	1.12	5.27	5.13	11.64	7.24	1502.5	44.75	159	2.5Y 4/1	10YR 2/1	78.00	20.60
PP	3	1	400	8708	424.5	4.01	1.12	3.46	4.44	15.44	7.65	1367.5	69.75	155	2.5Y 4/1	10YR 2/2	88.56	10.80
PP	3	1	500	3248	340.6	3.61277	1.0179	4.1152	5.1327	13.7016	7.74	1362.5	75.75	144	2.5Y 4/1	2.5Y 4/1	93.52	6.00
PP	3	1	600	1530	210.0	3.46	0.95	4.61	6.35	22.84	7.84	1692.5	124.75	140	2.5Y 4/2	2.5Y 4/1	89.44	8.00
PP	3	1	900	1395	112.8	2.98	0.91	1.48	2.26	12.07	7.96	730.0	144.75	134	2.5Y 6/2	10YR 6/2	97.08	2.40
PP	3	1	1200	630	8.6	2.28	0.55	4.28	6.70	10.98	8.29	422.5	75.75	134	2.5Y 6/3	10YR 6/2	84.56	12.40
PP 3-02				**Katspruit**														
PP	3	2	50	39960	3147.9	8.25	1.38	6.26	12.09	26.32	5.98	1802.5	95.50	305	2.5Y 2.5/1	2.5Y 2.5/1	83.12	17.60
PP	3	2	100	15788	1197.0	2.74	0.46	6.91	6.18	6.31	6.21	997.5	36.00	315	2.5Y 3/1	2.5Y 2.5/1	90.60	7.12
PP	3	2	150	7995	746.3	1.17	0.37	3.95	4.87	8.16	6.71	920.0	23.00	375	2.5Y 3/1	2.5Y 2.5/1	92.40	6.20
PP	3	2	200	5820	606.6	1.26	0.50	3.62	6.35	8.37	6.99	880.0	33.75	216	2.5Y 3/1	2.5Y 3/1	79.96	17.00
PP	3	2	250	5325	450.3	1.15	0.40	3.95	8.35	6.96	7.47	1165.0	28.25	272	2.5Y 3/1	2.5Y 3/1	85.20	13.40
PP	3	2	300	3555	370.6	0.90	0.53	3.29	7.22	9.13	8.03	1060.0	42.75	214	2.5Y 4/1	2.5Y 3/1	89.20	9.20
PP	3	2	400	2880	282.6	0.49	0.53	4.28	10.09	8.92	8.38	817.5	54.00	200	2.5Y 4/1	2.5Y 3/1	83.08	15.00
PP	3	2	500	2445	171.2	0.41	0.58	0.16	2.26	9.79	8.31	775.0	109.00	192	2.5Y 4/2	2.5Y 4/1	83.32	14.00
PP	3	2	600	2145	189.6	0.77	0.70	4.12	11.48	12.83	8.70	905.0	199.25	176	2.5Y 4/2	2.5Y 4/1	83.68	13.80
PP	3	2	900	1275	103.0	0.68	0.60	5.10	14.27	15.22	8.85	785.0	151.50	158	2.5Y 6/2	2.5Y 5/1	75.92	21.20
PP	3	2	1200	2175	105.9	0.15	0.50	5.10	16.01	15.01	8.81	610.0	92.00	166	2.5Y 6/3	2.5Y 5/2	74.32	22.92
PP 3-03				**Valsrivier**														
PP	3	3	50	8925	651.7	2.89	0.14	1.48	3.04	4.78	7.04	290.3	28.50	1620	5YR 5/1	2.5Y 3/1	96.20	3.00
PP	3	3	100	5910	620.9	1.66	0.27	3.29	7.39	6.74	7.92	1117.5	37.00	305	7.5YR 3/1	2.5Y 3/2	92.48	5.60
PP	3	3	150	3720	755.9	1.52	0.28	2.80	7.13	6.52	8.32	1515.0	34.50	270	7.5YR 3/1	2.5Y 3/2	90.08	8.00
PP	3	3	200	2220	380.8	1.09	0.24	2.27	7.48	8.70	8.69	1222.5	101.25	228	10YR 4/2	2.5Y 3/2	92.12	8.40
PP	3	3	250	2423	209.6	1.08	0.28	2.29	8.44	2.07	8.87	1025.0	93.00	198	10YR 4/2	10YR 3/2	89.24	9.40
PP	3	3	300	2235	177.5	1.04	0.30	2.42	8.79	8.05	8.97	305.3	61.50	194	10YR 4/2	10YR 3/2	91.68	7.80
PP	3	3	400	2175	172.9	1.27	0.41	3.46	11.48	8.70	8.85	271.0	27.50	144	7.5YR 3/1	10YR 3/1	82.68	15.80
PP	3	3	500	2295	175.6	1.41	0.45	3.95	14.09	13.27	8.83	274.3	37.75	132	7.5YR 3/1	10YR 3/1	68.76	29.92
PP	3	3	600	2940	206.8	1.60	0.54	3.29	8.61	15.55	8.86	263.8	22.25	126	10YR 3/1	10YR 3/1	77.28	19.72
PP	3	3	900	2835	149.7	0.94	0.51	4.44	15.31	12.40	8.77	337.8	25.25	122	10YR 3/1	2.5Y 3/1	75.48	22.40

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
PP	3	3	1200	2685	120.9	1.03	0.45	3.62	13.92	15.55	8.99	925.0	106.75	120	10YR 3/2	2.5Y 3/1	84.28	15.40
PL 4-01				**Champagne**														
PL	4	1	50	141000	12116.3	8.05	0.54	6.58	5.74	23.49	5.41	9050.0	82.50	172	10YR 2/1	10YR 2/1	84.88	13.59
PL	4	1	100	107010	6423.7	4.68	0.28	6.09	5.57	23.81	5.08	6525.0	47.75	148	10YR 2/1	10YR 2/1	83.15	12.47
PL	4	1	150	116963	5632.4	6.77	0.30	7.41	7.57	47.85	5.35	6575.0	42.75	142	10YR 2/1	10YR 2/1	83.68	13.59
PL	4	1	200	106750	6899.7	4.49	0.28	6.42	7.39	27.73	4.99	3815.0	28.75	134	10YR 2/1	10YR 2/1	87.57	9.72
PL	4	1	250	86550	173.5	4.32	0.28	4.94	6.44	20.12	5.04	3207.5	17.75	128	10YR 2/1	10YR 2/1	86.60	10.34
PL	4	1	300	91100	5179.6	4.23	0.27	4.28	4.52	21.75	4.93	2170.0	10.75	133	10YR 2/1	10YR 2/1	88.05	9.22
PL	4	1	400	85900	3595.4	4.50	0.23	5.43	6.87	13.16	4.82	1655.0	6.00	112	10YR 2/1	10YR 2/1	91.50	7.34
PL	4	1	500	24990	1096.4	2.27	0.10	2.11	2.26	11.74	4.98	347.3	2.00	226	10YR 3/1	10YR 2/1	98.35	0.59
PL	4	1	600	16770	745.0	1.87	0.06	1.55	1.06	7.50	5.28	206.0	1.50	540	10YR 3/1	10YR 2/2	97.83	1.09
PL	4	1	900	6360	347.9	1.16	0.04	0.74	0.50	4.78	4.99	116.8	1.50	750	10YR 5/1	10YR 3/1	98.73	0.22
PL	4	1	1200	1170	95.2	0.81	0.03	0.36	0.21	3.04	5.15	50.0	1.00	1070	10YR 7/1	10YR 4/2	99.32	0.34
PL 4-02				**Fernwood**														
PL	4	2	50	59565	3437.9	2.48	0.26	2.09	0.44	16.75	5.05	2315.0	11.25	1400	5YR 2.5/1	10YR 2/1	93.48	9.09
PL	4	2	100	41610	2784.2	2.59	0.21	2.40	0.45	16.53	4.89	1505.0	3.75	2040	7.5YR 5/1	10YR 2/1	92.40	7.72
PL	4	2	150	36810	1861.3	1.99	0.10	1.61	0.79	11.09	5.00	1360.0	2.75	1200	7.5YR 5/1	10YR 2/1	93.97	3.97
PL	4	2	200	22193	1469.1	2.56	0.09	1.48	0.70	10.22	5.26	1165.0	2.25	1500	10YR 4/1	10YR 2/1	97.00	0.59
PL	4	2	250	11918	776.9	1.94	0.06	1.10	0.70	5.87	5.47	411.0	1.50	1540	10YR 4/1	10YR 2/1	97.83	0.97
PL	4	2	300	8168	487.1	1.52	0.03	0.69	0.48	6.74	5.40	303.8	1.75	1180	2.5YR 4/1	10YR 2/1	98.40	0.84
PL	4	2	400	4635	74.9	1.01	0.03	0.48	0.47	2.83	5.64	114.0	1.25	1340	2.5YR 5/1	10YR 2/2	99.13	0.47
PL	4	2	500	2190	29.6	0.87	0.02	0.36	0.44	3.81	5.77	72.3	1.00	1370	2.5YR 5/1	10YR 3/1	98.52	0.34
PL	4	2	600	1643	163.1	0.94	0.02	0.30	0.51	3.59	5.89	54.5	1.25	980	2.5YR 6/2	10YR 3/2	99.60	0.09
PL	4	2	900	1350	138.4	0.79	0.04	0.33	0.83	3.70	5.79	48.8	1.25	1020	2.5YR 6/2	10YR 4/2	98.38	0.84
PL	4	2	1200	1800	123.9	0.64	0.04	0.28	0.42	3.70	5.58	58.0	1.50	1060	2.5YR 6/2	10YR 4/2	101.48	0.00
PL 4-03				**Fernwood**														
PL	4	3	50	27398	1602.6	3.01	0.16	1.25	0.20	6.63	5.18	363.0	13.75	3120	10YR 2/1	10YR 2/1	97.25	2.04
PL	4	3	100	20055	878.4	2.34	0.12	0.91	0.17	3.04	5.25	215.8	6.00	5120	10YR 3/1	10YR 2/1	98.40	2.29
PL	4	3	150	10973	750.1	1.96	0.10	0.67	0.16	2.72	5.58	145.3	4.25	8800	10YR 4/1	10YR 2/1	98.33	1.67
PL	4	3	200	5993	571.8	1.65	0.11	0.61	0.16	3.16	5.60	117.0	4.00	10000	10YR 4/1	10YR 2/1	98.13	1.54
PL	4	3	250	6833	459.4	1.69	0.08	0.53	0.13	2.71	5.61	100.0	3.50	9800	10YR 5/1	10YR 3/1	99.85	1.04
PL	4	3	300	4200	394.3	1.87	0.07	0.49	0.11	2.13	5.79	71.5	3.50	15200	10YR 5/1	10YR 3/1	99.75	0.67
PL	4	3	400	3165	292.3	1.25	0.04	0.28	0.10	1.73	5.99	55.8	3.00	15000	10YR 5/1	10YR 3/1	103.28	0.92
PL	4	3	500	2550	222.7	0.90	0.04	0.25	0.10	0.85	6.01	48.5	2.75	13800	10YR 5/1	2.5Y 3/1	99.38	1.17
PL	4	3	600	1995	238.6	0.94	0.04	0.23	0.10	0.92	6.13	36.3	2.75	14400	10YR 5/1	2.5Y 3/1	101.10	0.17
PL	4	3	900	1268	93.5	0.80	0.03	0.16	0.13	0.67	5.88	31.0	2.75	4050	10YR 6/1	2.5Y 3/2	113.25	0.17
PL	4	3	1200	682	59.1	0.58	0.02	0.13	0.21	0.70	5.31	20.5	2.50	1580	10YR 5/2	2.5Y 3/2	99.55	0.92

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
PL 4-04				**Fernwood**														
PL	4	4	50	23070	903.4	3.44	0.07	1.04	0.24	5.11	4.89	345.5	24.25	4160	10YR 3/1	10YR 2/1	98.05	1.22
PL	4	4	100	12420	488.5	2.60	0.04	0.77	0.21	4.89	5.02	285.3	11.00	5500	10YR 4/1	10YR 2/1	97.45	1.22
PL	4	4	150	9900	606.8	2.18	0.03	0.66	0.17	4.02	5.34	235.8	6.75	7700	2.5Y 5/1	2.5Y 2.5/1	97.23	0.72
PL	4	4	200	7590	425.4	1.84	0.02	0.54	0.14	3.26	5.48	211.3	4.50	9600	10YR 5/1	2.5Y 2.5/1	100.70	0.72
PL	4	4	250	7118	452.2	1.64	0.01	0.40	0.11	2.17	5.38	193.8	4.50	8700	2.5Y 5/1	2.5Y 2.5/1	99.08	0.47
PL	4	4	300	19470	380.1	1.62	0.02	0.43	0.14	2.07	5.66	176.0	3.75	10900	2.5Y 5/1	2.5Y 2.5/1	99.95	0.34
PL	4	4	400	5010	300.5	1.37	0.02	0.33	0.14	0.98	5.77	150.5	2.50	13900	10YR 5/1	10YR 2/2	99.30	0.34
PL	4	4	500	4200	240.1	1.48	0.02	0.35	0.16	2.28	6.09	145.8	3.00	13300	10YR 5/1	10YR 2/2	98.43	0.09
PL	4	4	600	2798	191.3	1.31	0.02	0.31	0.16	1.41	6.20	145.0	1.75	15100	2.5Y 5/1	2.5Y 3/2	99.45	0.09
PL	4	4	900	810	160.0	1.24	0.02	0.33	0.18	2.07	6.05	99.0	2.00	5200	10YR 5/2	2.5Y 3/2	99.37	0.34
PL	4	4	1200	6400	105.1	1.13	0.01	0.28	0.29	0.87	5.96	76.8	2.00	1940	7.5YR 7/2	10YR 3/2	99.48	0.22
PL 3-01				**Fernwood**														
PL	3	1	50	56598	6577.6	1.44	0.17	1.51	1.05	14.57	4.91	73500.0	13.00	222	10YR 2/1	10YR 2/1	93.95	4.65
PL	3	1	100	57240	4248.0	0.79	0.07	0.71	0.74	10.55	4.80	58750.0	7.25	284	10YR 2/1	10YR 2/1	91.48	7.52
PL	3	1	150	40425	3662.8	0.60	0.05	0.44	0.53	9.03	5.02	3710.0	7.00	290	10YR 2/1	10YR 2/1	93.10	7.03
PL	3	1	200	29400	2662.3	1.19	0.09	0.84	1.01	12.29	5.00	2797.5	6.00	362	10YR 2/1	10YR 2/1	94.70	4.03
PL	3	1	250	25095	1840.5	1.12	0.06	0.76	0.94	8.16	4.95	2080.0	4.50	435	10YR 2/1	10YR 2/1	95.43	2.27
PL	3	1	300	23425	86.0	0.85	0.04	0.58	0.74	4.78	5.23	967.5	2.50	560	10YR 3/2	10YR 2/1	100.80	0.03
PL	3	1	400	4335	191.0	0.34	0.03	0.26	0.36	1.63	5.25	261.0	1.00	1100	10YR 4/2	10YR 3/2	98.78	0.02
PL	3	1	500	2025	121.7	0.28	0.02	0.21	0.30	1.20	5.07	190.0	1.00	1090	10YR 5/3	2.5Y 3/2	100.78	0.15
PL	3	1	600	2843	93.1	0.22	0.02	0.21	0.29	0.98	5.32	171.3	1.00	1520	10YR 6/2	2.5Y 3/2	99.82	0.53
PL	3	1	900	2565	91.5	0.15	0.03	0.20	0.23	0.87	5.48	152.5	1.00	1560	10YR 6/2	2.5Y 4/3	99.45	0.40
PL	3	1	1200	2580	124.4	0.35	0.04	0.30	0.21	0.87	6.00	208.0	1.50	2600	10YR 6/2	10YR 4/3	98.35	1.02
PL 3-02				**Longlands**														
PL	3	2	50	28598	1636.1	1.90	0.08	1.53	0.70	12.18	5.13	3125.0	8.75	1120	10YR 2/1	10YR 2/1	95.20	2.86
PL	3	2	100	32490	1863.5	1.87	0.08	1.60	1.29	9.79	5.10	3805.0	4.50	810	10YR 2/1	10YR 2/1	95.10	2.16
PL	3	2	150	30180	1458.6	1.73	0.06	1.28	1.05	14.68	5.09	3325.0	4.50	820	10YR 2/1	10YR 2/1	95.76	3.36
PL	3	2	200	15975	1012.0	1.40	0.03	0.76	0.71	8.48	5.20	2270.0	2.50	1490	10YR 3/1	10YR 2/1	97.42	1.86
PL	3	2	250	11895	829.7	1.72	0.03	0.61	0.50	7.07	5.30	1500.0	2.25	2140	10YR 3/1	10YR 2/1	97.12	1.96
PL	3	2	300	5970	382.3	1.34	0.02	0.40	0.35	4.46	5.51	745.0	1.50	3950	10YR 4/1	10YR 2/1	98.52	1.46
PL	3	2	400	1770	179.2	0.99	0.02	0.23	0.37	4.13	5.51	207.5	1.00	5750	7.5YR 5/1	10YR 2/2	98.98	0.96
PL	3	2	500	870	145.9	0.89	0.03	0.20	0.37	2.94	5.55	161.3	0.75	7100	10YR 6/2	10YR 3/2	99.16	0.96
PL	3	2	600	1355	113.2	0.89	0.02	0.18	0.19	2.72	5.68	133.8	0.25	8000	10YR 6/2	10YR 3/2	99.44	0.86
PL	3	2	900	1000	82.7	0.93	0.01	0.16	0.23	2.50	5.61	126.0	1.00	5300	2.5Y 6/2	2.5Y 4/2	99.06	0.56
PL	3	2	1200	725	51.5	0.84	0.02	0.16	0.21	3.26	5.49	88.8	1.00	3900	2.5Y 7/1	2.5Y 4/2	98.74	0.16
PL 3-03				**Fernwood**														

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
PL	3	3	50	31800	1927.6	2.73	0.13	2.60	0.26	7.61	5.27	2447.5	9.50	2560	10YR 2/1	10YR 2/1	93.83	4.54
PL	3	3	100	22335	1490.6	2.19	0.11	2.16	0.23	6.42	5.41	1950.0	3.75	3550	10YR 3/1	10YR 2/1	99.48	0.17
PL	3	3	150	14610	1217.6	1.58	0.06	1.30	0.24	6.42	5.60	1820.0	2.75	4900	10YR 3/1	10YR 2/1	96.73	2.04
PL	3	3	200	15645	744.3	1.35	0.06	1.02	0.22	4.46	5.64	1505.0	1.75	5200	2.5Y 3/1	10YR 2/1	97.83	0.92
PL	3	3	250	11003	747.6	1.08	0.05	0.67	0.22	3.59	5.81	1172.5	1.50	6800	2.5Y 4/1	10YR 2/1	93.95	0.67
PL	3	3	300	7050	454.0	0.73	0.05	0.41	0.22	2.39	5.94	860.0	0.75	9100	2.5Y 4/1	10YR 2/1	99.50	0.42
PL	3	3	400	5303	326.4	0.53	0.03	0.33	0.17	1.85	6.20	357.5	0.50	10600	10YR 5/1	2.5Y 3/1	98.68	0.54
PL	3	3	500	3638	190.4	0.32	0.02	0.21	0.16	1.30	6.28	306.0	0.75	14200	10YR 5/2	2.5Y 3/1	100.00	0.04
PL	3	3	600	3225	173.4	0.31	0.02	0.20	0.13	1.52	6.30	224.0	0.50	14000	10YR 6/2	2.5Y 3/1	100.63	0.29
PL	3	3	900	2970	96.0	0.18	0.02	0.15	0.11	1.20	6.30	132.8	0.50	10300	2.5Y 6/2	2.5Y 3/2	100.20	0.04
PL	3	3	1200	2588	57.4	0.24	0.02	0.16	0.17	1.09	6.45	114.3	0.25	10000	2.5Y 6/2	2.5Y 4/2	99.25	0.04
PL 3-04				**Fernwood**														
PL	3	4	50	12503	872.7	0.82	0.06	0.77	0.23	6.74	5.35	1900.0	4.75	7900	2.5Y 4/1	2.5Y 2.5Y/1	97.45	2.45
PL	3	4	100	6623	547.5	0.51	0.03	0.49	0.15	8.92	5.32	637.5	3.75	8100	2.5Y 5/1	2.5Y 2.5Y/1	98.38	1.32
PL	3	4	150	7958	382.2	0.06	0.03	0.46	0.15	5.44	5.35	395.3	3.25	9600	10YR 5/1	2.5Y 2.5Y/1	98.60	1.45
PL	3	4	200	5615	394.5	1.82	0.03	0.41	0.12	5.00	5.44	777.5	3.75	10400	10YR 5/1	2.5Y 2.5Y/1	98.73	1.33
PL	3	4	250	5295	298.5	0.96	0.02	0.33	0.11	4.13	5.51	340.8	2.00	13000	10YR 5/1	2.5Y 2.5Y/1	98.65	1.45
PL	3	4	300	4388	212.3	0.94	0.02	0.38	0.17	5.22	5.63	339.3	2.00	15000	10YR 5/1	2.5Y 2.5Y/1	100.13	0.00
PL	3	4	400	4100	188.0	0.88	0.01	0.30	0.16	8.16	5.97	268.5	1.25	15800	10YR 5/2	2.5Y 3/1	98.80	0.45
PL	3	4	500	2767	204.3	0.64	0.02	0.30	0.16	8.70	6.30	257.5	1.25	15000	10YR 5/2	2.5Y 3/1	100.18	0.00
PL	3	4	600	2360	156.1	0.79	0.01	0.26	0.30	6.09	6.29	242.3	1.00	16600	10YR 6/2	2.5Y 3/1	102.43	0.20
PL	3	4	900	2020	142.4	0.58	0.01	0.16	0.15	5.44	6.20	146.0	1.00	19000	10YR 6/2	2.5Y 4/2	99.13	0.82
PL	3	4	1200	955	6352.5	0.59	0.01	0.18	0.13	4.57	6.45	130.8	1.00	17000	10YR 6/2	10YR 4/2	99.43	0.70
PL 6-01				**Fernwood**														
PL	6	1	50	20122	1380.6	0.81	0.10	0.71	0.21	3.37	5.44	1150.0	7.75	2040	10YR 2/1	10YR 2/1	95.48	4.84
PL	6	1	100	14175	867.5	0.81	0.10	0.95	0.30	5.98	5.29	905.0	1.25	4060	2.5Y 2.5/1	10YR 2/1	95.55	3.72
PL	6	1	150	10035	581.6	0.27	0.07	0.61	0.31	4.68	5.35	249.3	1.75	4140	2.5Y 3/1	10YR 2/1	98.08	1.47
PL	6	1	200	14085	663.6	0.20	0.12	0.48	0.26	3.15	5.45	197.8	1.00	6350	2.5Y 3/1	10YR 2/1	98.25	1.09
PL	6	1	250	12930	540.3	0.78	0.08	0.51	0.35	7.39	5.46	161.3	1.00	6000	2.5Y 3/1	10YR 2/1	95.28	3.34
PL	6	1	300	9975	528.5	0.51	0.05	0.38	0.29	4.57	5.74	122.0	1.00	6700	2.5Y 4/1	10YR 2/1	96.83	2.47
PL	6	1	400	5025	327.7	0.46	0.04	0.44	0.23	5.33	5.69	90.0	0.50	6550	2.5Y 5/1	10YR 2/1	95.68	3.59
PL	6	1	500	5378	218.9	0.47	0.03	0.38	0.22	4.68	5.65	67.0	0.75	7600	2.5Y 4/1	2.5Y 2.5/1	96.60	2.97
PL	6	1	600	4935	181.3	0.49	0.03	0.38	0.18	3.91	5.86	49.3	0.50	8500	2.5Y 4/1	2.5Y 2.5/1	97.55	2.09
PL	6	1	900	3090	112.5	0.57	0.02	0.36	0.13	3.70	5.97	38.5	0.50	10000	2.5Y 5/2	2.5Y 3/2	97.80	1.47
PL	6	1	1200	2130	90.6	0.56	0.02	0.31	0.19	1.30	5.95	56.3	0.25	5050	10YR 6/2	2.5Y 4/2	99.32	0.09
PL 6-02				**Fernwood**														
PL	6	2	50	5588	103.8	2.11	0.05	0.16	0.06	3.81	5.57	139.25	23.25	13800	10YR 5/2	2.5Y 3/2	99.98	0.42

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
PL	6	2	100	2340	239.0	2.22	0.04	0.15	0.08	4.02	4.71	117.75	2.50	15700	10YR 5/2	2.5Y 3/2	100.18	0.42
PL	6	2	150	3075	224.5	2.26	0.03	0.15	0.09	3.37	4.61	115.25	1.75	19200	10YR 5/2	2.5Y 3/2	99.03	0.04
PL	6	2	200	2783	178.5	2.30	0.04	0.15	0.10	3.70	4.86	121.50	1.50	18600	10YR 5/2	2.5Y 3/2	100.13	0.04
PL	6	2	250	7125	221.4	2.18	0.03	0.13	0.10	3.37	4.56	114.00	1.25	11700	10YR 5/2	2.5Y 3/2	98.95	0.42
PL	6	2	300	4058	186.7	2.04	0.04	0.15	0.21	1.96	4.67	116.75	1.00	23000	10YR 5/2	2.5Y 3/2	99.18	0.29
PL	6	2	400	3495	258.7	1.98	0.03	0.12	0.09	4.02	4.69	117.25	1.00	23700	10YR 5/2	2.5Y 3/2	100.55	0.17
PL	6	2	500	4785	287.5	2.17	0.05	0.13	0.23	3.48	4.67	116.75	1.25	22800	10YR 5/2	2.5Y 3/2	99.33	0.67
PL	6	2	600	4163	141.9	2.22	0.05	0.13	0.23	3.37	3.87	96.75	0.50	3050	10YR 5/2	2.5Y 3/2	98.78	0.67
PL	6	2	900	3190	144.0	2.11	0.02	0.15	0.10	1.85	4.72	118.00	0.50	25000	10YR 5/2	2.5Y 3/2	99.67	0.79
PL	6	2	1200	2760	67.7	1.64	0.01	0.12	0.10	1.20	4.37	109.25	0.25	10500	10YR 6/2	2.5Y 4/2	98.13	1.17
PL 6-03				**Fernwood**														
PL	6	3	50	5625	259.9	0.66	0.03	0.21	0.17	5.00	4.86	87.8	4.25	10000	10YR 6/2	10YR 3/2	97.25	2.44
PL	6	3	100	7455	227.1	0.44	0.02	0.13	0.12	5.00	4.82	65.3	2.25	11300	10YR 5/2	10YR 4/2	97.98	2.06
PL	6	3	150	3698	154.0	0.50	0.02	0.12	0.10	4.24	4.92	47.0	1.50	11500	10YR 5/2	10YR 3/2	98.70	1.69
PL	6	3	200	2865	209.5	0.56	0.03	0.15	0.19	5.55	4.94	54.0	1.00	18200	10YR 5/2	10YR 3/2	98.85	1.44
PL	6	3	250	2460	157.5	0.52	0.02	0.12	0.15	4.46	4.97	50.5	0.50	18500	10YR 6/2	10YR 3/2	98.02	1.81
PL	6	3	300	3015	175.9	0.60	0.02	0.15	0.12	4.78	4.96	43.8	0.50	19300	10YR 5/2	10YR 3/2	98.48	2.06
PL	6	3	400	2707	24.6	0.51	0.02	0.12	0.17	4.57	5.07	51.0	1.00	23200	10YR 5/2	10YR 3/2	97.63	2.81
PL	6	3	500	2347	167.0	0.58	0.01	0.10	0.10	4.78	5.04	36.5	0.75	21200	10YR 5/2	10YR 3/2	98.45	1.56
PL	6	3	600	2615	140.0	0.53	0.01	0.10	0.10	5.87	4.78	29.8	0.50	16600	10YR 5/2	10YR 3/2	97.65	2.94
PL	6	3	900	2037	126.0	0.53	0.01	0.08	0.10	4.57	4.77	33.5	0.75	16100	10YR 5/2	10YR 3/2	99.08	1.19
PL	6	3	1200	1593	75.7	0.54	0.01	0.08	0.10	4.78	4.95	17.8	0.50	17400	10YR 6/2	10YR 4/2	98.39	2.19
PL 5-01				**Fernwood**														
PL	5	1	50	11948	532.7	2.54	0.12	0.46	0.10	3.15	5.03	1580.0	10.25	4600	10YR 3/1	10YR 2/1	96.08	3.42
PL	5	1	100	7035	488.5	1.65	0.12	0.44	0.12	3.29	4.95	635.0	4.25	4600	10YR 3/1	10YR 2/1	99.80	0.29
PL	5	1	150	5070	468.6	1.15	0.06	0.33	0.08	2.47	4.95	295.8	2.75	5800	10YR 3/1	10YR 2/1	96.28	2.17
PL	5	1	200	7485	359.9	1.18	0.05	0.33	0.07	2.94	4.96	290.0	2.75	7000	10YR 4/1	10YR 2/1	97.75	1.79
PL	5	1	250	6053	290.9	0.80	0.05	0.28	0.10	1.53	5.06	215.8	2.00	9100	10YR 4/1	10YR 2/1	98.27	1.67
PL	5	1	300	5603	225.1	0.64	0.04	0.26	0.06	1.67	5.14	140.0	1.50	8900	10YR 4/1	10YR 2/1	98.15	1.79
PL	5	1	400	4605	187.3	0.64	0.03	0.28	0.09	1.63	5.44	87.3	1.50	11200	10YR 4/2	10YR 2/1	99.25	1.29
PL	5	1	500	3660	158.5	0.71	0.03	0.25	0.07	1.56	5.54	76.0	1.00	13800	10YR 4/2	10YR 2/1	100.22	0.00
PL	5	1	600	2873	153.9	0.58	0.03	0.23	0.08	1.02	5.35	79.5	1.00	13200	10YR 5/2	10YR 3/1	98.38	2.17
PL	5	1	900	6375	90.2	0.55	0.03	0.20	0.06	0.74	5.46	60.8	1.00	16300	10YR 5/2	10YR 3/2	99.38	0.42
PL	5	1	1200	2240	69.2	0.42	0.03	0.18	0.05	0.00	5.54	41.0	1.00	15600	10YR 6/2	2.5Y 4/2	99.02	0.79
PL 5-02				**Fernwood**														
PL	5	2	50	11243	609.7	2.06	0.15	0.72	0.15	4.24	5.30	350.5	14.50	3420	10YR 4/1	10YR 2/1	97.55	1.79
PL	5	2	100	6683	560.1	1.57	0.08	0.64	0.11	3.48	5.12	249.3	7.00	3560	10YR 4/1	10YR 2/1	97.93	1.79

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
PL	5	2	150	5805	426.8	1.08	0.06	0.48	0.07	4.78	5.03	168.0	4.00	4700	10YR 4/1	10YR 2/1	97.68	2.42
PL	5	2	200	5813	347.8	1.06	0.05	0.44	0.05	2.83	5.02	133.5	3.75	5550	10YR 4/1	10YR 2/1	98.83	1.04
PL	5	2	250	4710	288.4	1.05	0.04	0.46	0.08	4.57	5.05	97.3	2.50	5430	10YR 4/2	2.5Y 3/2	96.52	2.29
PL	5	2	300	3360	274.8	0.94	0.04	0.43	0.05	2.83	5.30	64.5	1.25	7600	10YR 4/2	2.5Y 3/2	98.65	1.04
PL	5	2	400	2453	203.7	0.83	0.02	0.38	0.04	2.28	5.16	61.3	1.25	7800	10YR 4/2	2.5Y 3/2	98.43	2.04
PL	5	2	500	2303	194.9	0.85	0.02	0.38	0.06	1.96	5.07	47.0	0.75	8100	10YR 4/2	2.5Y 3/1	97.00	3.04
PL	5	2	600	1800	177.9	0.16	0.02	0.38	0.07	2.28	5.19	45.0	1.25	10000	10YR 5/2	2.5Y 3/1	97.10	3.17
PL	5	2	900	6215	25.6	0.76	0.03	0.35	0.10	3.48	5.25	37.8	1.00	10500	10YR 5/2	2.5Y 3/2	97.75	2.67
PL	5	2	1200	440	72.0	0.52	0.02	0.28	0.03	0.98	5.30	32.5	1.50	13200	10YR 6/2	2.5Y 4/2	100.14	0.00
PL 5-03				**Fernwood**														
PL	5	3	50	7043	336.2	2.24	0.11	0.43	0.23	3.59	5.33	143.8	24.75	6900	2.5Y 5/2	2.5Y 3/2	98.85	1.75
PL	5	3	100	3878	340.1	2.10	0.07	0.40	0.13	3.70	5.26	162.0	20.25	7100	2.5Y 5/2	2.5Y 3/2	100.00	0.62
PL	5	3	150	4365	243.8	1.87	0.05	0.33	0.08	4.35	5.03	118.5	6.75	7800	10YR 5/2	2.5Y 3/2	100.23	0.87
PL	5	3	200	5438	228.4	1.58	0.03	0.25	0.07	3.04	4.95	99.8	2.75	10400	10YR 5/2	2.5Y 3/2	99.07	1.00
PL	5	3	250	4605	212.7	1.79	0.04	0.25	0.06	2.39	4.84	98.0	2.50	13600	10YR 5/2	2.5Y 3/2	100.50	1.00
PL	5	3	300	4905	164.2	1.82	0.04	0.25	0.10	4.13	4.88	99.0	2.75	13200	10YR 5/2	2.5Y 3/2	98.93	1.38
PL	5	3	400	4065	194.5	1.80	0.05	0.25	0.21	2.17	4.72	89.5	1.50	9900	10YR 5/2	2.5Y 3/2	99.03	1.37
PL	5	3	500	3705	167.3	1.96	0.06	0.23	0.23	2.61	4.73	84.3	1.25	15000	10YR 5/2	2.5Y 3/2	99.30	1.38
PL	5	3	600	3623	101.1	1.86	0.05	0.18	0.23	3.81	4.72	66.0	1.00	18600	10YR 5/2	2.5Y 3/2	99.53	1.50
PL	5	3	900	3240	78.2	1.79	0.04	0.13	0.23	4.57	4.69	47.8	1.00	23600	10YR 5/2	2.5Y 3/2	101.05	0.00
PL	5	3	1200	2505	83.7	2.01	0.03	0.12	0.09	2.39	4.65	29.8	1.00	25200	2.5Y 5/2	2.5Y 3/2	100.45	0.00
DP 1-01				**Westleigh**														
DP	1	1	50	61020	6141.8	11.77	2.84	6.53	3.81	56.55	5.99	3520	49.4	420			45.73	51.67
DP	1	1	100	29835	2814.0	9.09	2.64	6.64	3.60	22.40	6.17	3232	8.8	380			46.40	53.33
DP	1	1	150	22553	1761.2	8.07	2.56	6.82	4.02	19.79	6.2	3120	4.4	300			52.60	48.33
DP	1	1	200	16628	1724.9	7.38	2.33	6.71	4.23	21.53	6.4	3640	2.6	260			47.30	53.33
DP	1	1	250	15345	1573.0	7.46	2.39	6.96	4.68	20.12	6.39	3880	2.2	220			48.43	51.67
DP	1	1	300	16583	1377.6	6.36	2.03	5.99	4.19	20.66	6.46	3180	2.2	no soil			53.70	46.67
DP	1	1	400	12833	1252.4	7.99	2.57	7.68	6.05	58.72	6.32	4820	2.2	190			48.13	53.33
DP	1	1	500	10768	800.8	6.20	2.02	6.22	5.45	18.81	6.38	4440	1.6	180			50.38	47.50
DP	1	1	600	7673	721.9	6.05	1.92	6.35	5.63	22.29	6.55	4460	1.8	170			53.68	45.00
DP	1	1	900	5768	535.4	5.75	1.88	6.22	6.01	16.53	6.85	5040	3.6	150			54.48	43.75
DP	1	1	1200	2985	999.3	4.26	1.26	5.09	5.12	15.88	7.36	7520	7	160			68.58	30.00
DP 1-02				**Longlands**														
DP	1	2	50	28903	565.2	8.24	1.33	3.49	1.56	19.79	6.06	2360	31.2	590			63.13	38.33
DP	1	2	100	16770	1651.6	6.19	1.15	3.53	1.89	13.16	6.28	3500	14.2	530			66.90	33.33
DP	1	2	150	11903	1069.2	5.62	1.16	3.93	2.19	13.59	6.28	4100	8.8	560			74.57	26.67

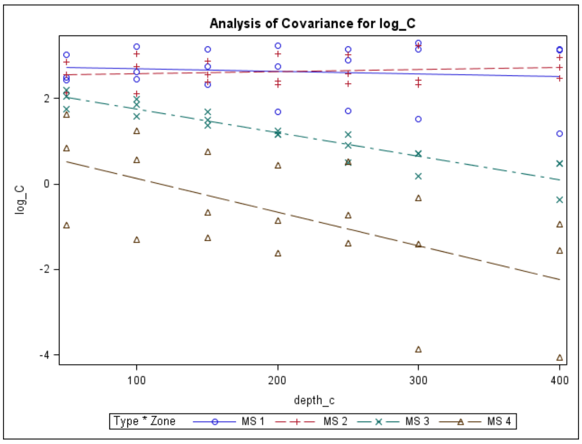
Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
DP	1	2	200	10043	789.3	5.40	1.23	4.27	2.58	16.42	7.2	3248	7.2	400			71.50	28.33
DP	1	2	250	9203	734.9	5.01	1.27	4.67	2.96	11.31	7.13	3234	4.6	380			67.70	30.00
DP	1	2	300	7045	737.6	4.75	1.25	4.82	3.24	17.29	7.27	3220	3	330			75.57	25.00
DP	1	2	400	6698	650.7	4.91	1.29	5.20	3.62	14.68	6.72	4440	3	200			67.03	30.00
DP	1	2	500	4755	436.7	3.60	1.00	4.25	3.11	10.77	7.6	6280	2.6	300			70.10	30.00
DP	1	2	600	2456	453.4	2.63	0.76	3.47	2.81	9.79	7.83	8400	3.2	320			81.43	18.33
DP	1	2	900	3263	298.1	2.81	0.81	3.75	3.42	11.09	8.17	5440	7.8	250			77.47	23.33
DP	1	2	1200	3015	176.6	2.95	0.77	3.96	3.56	12.40	7.92	5680	13.8	220			75.43	25.00
DP 1-03				**Kinkelbos**														
DP	1	3	50	30360	1776.1	11.24	0.86	3.15	0.92	18.38	6.99	2388	48.4	550			74.97	25.00
DP	1	3	100	18713	1322.3	5.57	0.42	2.10	0.83	11.42	7.92	2084	18	1300			75.29	23.33
DP	1	3	150	10485	816.1	2.64	0.31	1.80	0.83	8.16	5.65	2100	5.4	1300			90.85	8.75
DP	1	3	200	7770	588.6	2.45	0.36	2.23	1.07	8.37	6.43	2310	3.6	2000			85.20	16.25
DP	1	3	250	5015	484.1	2.33	0.36	2.44	1.23	9.35	6.75	2676	3.6	1100			81.68	18.75
DP	1	3	300	3255	302.5	3.07	0.49	3.69	1.88	10.22	7.09	7000	4.6	550			78.60	20.00
DP	1	3	400	4013	277.8	2.57	0.45	3.21	1.69	8.70	6.53	6880	5.2	650			80.33	20.00
DP	1	3	500	3158	231.8	3.54	0.73	4.80	2.89	13.81	7.65	13740	5.4	450			80.68	18.75
DP	1	3	600	1875	330.5	2.43	0.58	3.55	2.49	11.74	8.2	4560	4.6	470			76.93	25.00
DP	1	3	900	1718	264.5	2.94	0.70	4.23	3.81	13.81	No soi	5520	14.2	no soil			78.30	22.50
DP	1	3	1200	2070	250.7	5.24	0.71	4.40	4.59	10.98	No soi	3440	28.8	no soil			77.80	23.33
DP 1-04				**Longlands**														
DP	1	4	50	13155	968.6	11.33	0.30	1.48	0.10	11.20	7.92	3760	71.6	1300			87.10	13.33
DP	1	4	100	10350	685.0	7.08	0.18	0.95	0.07	4.78	7.95	3160	34.4	1800			91.60	10.00
DP	1	4	150	5460	455.0	4.16	0.09	0.52	0.03	5.65	7.98	4240	21	2000			91.87	10.00
DP	1	4	200	3488	317.7	1.79	0.04	0.24	0.06	3.81	8.19	3218	6.8	3100			93.27	6.67
DP	1	4	250	2788	290.8	1.59	0.04	0.25	0.12	3.15	8.09	2540	5	2300			93.57	6.67
DP	1	4	300	2993	302.5	1.82	0.15	1.70	0.79	6.20	8.05	2910	4.4	1200			84.20	15.00
DP	1	4	400	3398	414.1	2.59	0.41	3.91	2.35	7.50	7.84	6660	5.4	4900			79.33	21.67
DP	1	4	500	1975	158.6	8.44	2.68	5.14	1.72	22.84	8.41	1444	7.4	600			89.57	8.33
DP	1	4	600	2415	183.8	6.43	1.87	4.31	1.59	18.05	8.7	1482	23.2	310			83.33	16.67
DP	1	4	900	1515	177.5	5.35	1.63	3.55	1.37	18.60	8.72	696	76.2	180			74.23	25.00
DP	1	4	1200	3109	63.7	1.16	0.21	2.02	1.48	6.74	9.21	836	38.8	150			68.07	31.67
DP 2-01				**Katspruit**														
DP	2	1	50	28688	1487.5	1.81	0.66	4.57	4.70	13.38	5.92	2520	108.6	450			51.57	46.67
DP	2	1	100	25113	2600.0	2.30	0.70	3.74	5.51	13.70	6.67	2844	108.4	480			53.16	45.00
DP	2	1	150	15000	1422.8	4.81	0.97	5.92	8.97	19.03	6.7	2030	68.4	590			67.67	31.67
DP	2	1	200	12023	1039.9	9.42	3.20	5.86	1.97	55.35	6.73	2108	65.6	570			61.07	36.67

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
DP	2	1	250	12240	1172.7	6.92	2.06	4.81	1.83	18.81	6.24	2192	67.8	500			57.67	40.00
DP	2	1	300	11183	983.9	6.18	1.77	4.60	1.82	19.79	5.59	2222	66.4	430			58.00	40.00
DP	2	1	400	9195	687.5	4.48	1.07	3.30	1.28	18.16	5.99	2054	60	450			62.80	35.00
DP	2	1	500	4975	735.3	4.52	1.08	3.76	1.62	12.18	6.46	1786	51.8	350			65.13	31.67
DP	2	1	600	3499	348.0	3.08	0.83	3.14	1.42	10.77	7.17	1658	33.4	340			76.43	23.33
DP	2	1	900	3139	247.2	4.12	1.03	4.03	1.92	11.31	6.79	2996	34.4	360			81.43	18.33
DP	2	1	1200	3026	248.4	3.74	1.04	3.74	1.91	11.31	7	1560	35.4	400			90.23	8.33
DP 2-02				**Katspruit**														
DP	2	2	50	29655	3819.2	10.59	2.89	6.35	1.84	68.51	5.79	2418	109.8	300			50.97	46.67
DP	2	2	100	28470	3340.0	10.60	2.78	6.23	2.07	55.46	6.01	2848	92.2	430			50.83	46.67
DP	2	2	150	23603	1205.3	9.52	2.23	5.53	1.88	21.31	6.02	3032	94.8				54.50	46.67
DP	2	2	200	17460	906.4	8.08	1.96	5.25	2.04	21.20	6.04	4820	76.8				54.13	45.00
DP	2	2	250	16823	744.5	7.26	1.80	4.85	1.88	17.62	5.63	2486	88.8	570			53.77	43.33
DP	2	2	300	12833	451.9	11.25	2.12	7.76	3.36	19.36	6.73	2354	86	600			55.20	46.67
DP	2	2	400	15630	467.0	11.10	1.99	7.75	3.53	26.42	6.89	2500	102.4	460			60.50	36.67
DP	2	2	500	7298	387.2	10.11	1.75	7.92	4.14	20.66	7.51	2232	82.4	400			61.70	40.00
DP	2	2	600	8648	718.1	11.90	1.88	8.26	4.07	24.79	6.98	1508	54.4	400			54.57	43.33
DP	2	2	900	5445	433.5	8.13	1.35	6.28	4.05	15.88	6.94	1608	53.6	450			64.67	33.33
DP	2	2	1200	3218	280.3	7.37	1.22	6.44	3.58	15.99	7.22	2038	41.2	530			69.70	30.00
DP 2-03				**Kroonstad**														
DP	2	3	50	26333	1139.1	10.26	2.19	6.44	1.63	21.10	5.94	1882	29.8	720			64.40	35.00
DP	2	3	100	15808	667.2	9.60	1.75	6.11	1.80	22.07	6.05	1588	26.6	700			69.30	31.67
DP	2	3	150	11348	446.6	8.53	1.53	6.43	1.70	19.79	5.72	1912	66.4	730			64.60	33.33
DP	2	3	200	9473	548.4	8.91	1.52	6.76	1.84	17.29	7.77	1482	27.8	620			61.60	36.67
DP	2	3	250	8460	750.3	7.33	1.24	5.45	1.60	15.12	6.55	1126	40.4	850			70.27	26.67
DP	2	3	300	7343	633.5	6.15	0.98	4.46	1.39	15.77	6.62	1298	66.6	750			72.50	25.00
DP	2	3	400	5168	401.5	5.35	0.84	4.13	1.41	13.81	6.98	2078	36.6	950			78.73	20.00
DP	2	3	500	4650	432.7	9.18	1.35	7.26	3.46	19.25	7.26	1902	39	450			62.75	35.00
DP	2	3	600	3743	418.9	7.65	1.14	6.11	3.03	15.01	7.57	1136	32.4	560			68.20	30.00
DP	2	3	900	2243	313.6	4.73	0.71	3.80	1.77	8.81	7.66	930	59.4	750			81.65	18.75
DP	2	3	1200	1268	248.3	4.07	0.48	1.68	0.51	7.94	7.99	776	54.6	540			80.73	20.00
DP 2-04				**Montagu**														
DP	2	4	50	11235	1153.5	3.00	0.47	2.36	1.19	6.63	8.5	816	42.6	1400			89.50	11.25
DP	2	4	100	4553	467.9	5.18	0.74	4.79	3.24	12.61	6.8	800	30.6	1200			87.78	12.50
DP	2	4	150	3120	436.3	2.87	0.46	2.35	1.28	7.07	6.94	1172	37	950			83.70	15.00
DP	2	4	200	3428	313.2	3.67	0.65	3.63	1.88	10.22	6.94	1212	37.4	630			83.00	17.50
DP	2	4	250	3190	505.8	3.58	0.70	3.80	3.12	10.87	7.05	1528	37.2	530			78.20	20.00

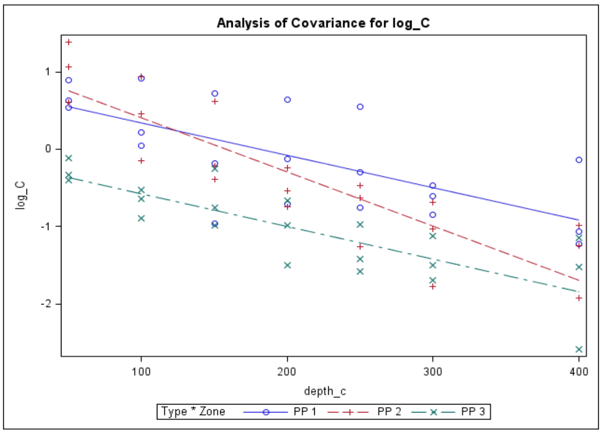
Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
DP	2	4	300	2888	325.7	4.09	0.86	4.29	3.91	11.20	7.19	848	57.6	400			79.90	20.00
DP	2	4	400	4365	138.3	3.66	0.77	3.80	3.71	10.66	7.77	582	60.4	400			73.10	25.00
DP	2	4	500	1430	121.1	4.89	1.03	4.95	5.42	14.57	8.36	560	53.4	320			72.35	25.00
DP	2	4	600	563	300.9	6.54	1.02	4.95	7.62	13.59	8.82	1358	2.2	290			73.15	26.25
DP	2	4	900	1540	178.2	13.20	1.05	6.10	10.19	15.88	9.35	1756	2.8	250			73.80	25.00
DP	2	4	1200	1425	180.7	12.22	0.92	5.28	11.15	14.14	9.67	1708	15.8	260			90.00	10.00
DP 2-05				**Sepane**														
DP	2	5	50	6953	681.8	1.95	2.07	0.81	0.55	6.09	9.87	1364	33.6	480			94.35	7.50
DP	2	5	100	4988	461.5	1.11	0.42	0.63	0.37	5.00	8.25	702	55	520			81.75	20.00
DP	2	5	150	2820	1054.8	0.66	0.17	0.47	0.37	3.91	6.89	2892	52	1100			94.75	5.00
DP	2	5	200	5838	584.7	1.31	0.43	3.52	7.06	8.05	6.35	2692	56.6	180			80.50	21.25
DP	2	5	250	5280	363.1	1.32	0.48	3.84	6.64	9.90	6.72	3018	50.2	180			78.98	21.25
DP	2	5	300	4838	285.3	1.38	0.52	4.19	8.35	9.57	7.06	2446	53.2	150			87.60	15.00
DP	2	5	400	3278	245.9	1.36	0.42	3.19	5.92	7.50	7.84	2076	53.8	170			76.63	22.50
DP	2	5	500	3123	147.3	1.49	0.64	4.54	10.44	10.11	8.49	1132	31.2	110			75.88	25.00
DP	2	5	600	2045	131.5	15.85	1.41	8.51	7.48	21.53	8.71	542	33.2	110			74.70	25.00
DP	2	5	900	3008	122.3	15.70	1.33	7.69	7.22	12.72	9	514	26.8	75			73.68	26.25
DP	2	5	1200	766	287.9	15.80	1.26	7.89	8.18	22.18	9.11	2266	21.8	65			53.58	45.00
DP 3-01				**Katspruit**														
DP	3	1	50	34260	2588.0	18.02	1.22	7.62	6.05	21.10	9.1	1566	3.8	300			92.74	8.33
DP	3	1	100	21953	1072.4	13.42	1.06	6.61	6.03	17.62	6.22	1360	0.8	330			54.60	46.67
DP	3	1	150	19725	1693.5	8.10	0.85	5.12	6.57	17.94	6.92	1036	1	350			54.07	46.67
DP	3	1	200	15838	1359.1	12.23	1.20	4.46	3.34	18.81	7.39	974	1	340			47.93	53.33
DP	3	1	250	13403	1092.5	11.24	0.88	3.64	3.36	17.83	7.66	922	1.4	300			50.93	46.25
DP	3	1	300	2603	762.7	1.51	0.60	4.13	8.22	11.20	7.91	802	1.8	290			52.15	45.00
DP	3	1	400	2775	500.4	1.38	0.60	4.13	8.15	10.22	8.08	624	21.6	250			57.60	43.75
DP	3	1	500	2175	313.2	1.34	0.63	4.47	9.40	12.61	8.34	526	41.8	270			58.93	41.25
DP	3	1	600	4395	221.9	24.66	1.91	7.27	4.12	31.43	8.5	574	52	250			60.75	37.50
DP	3	1	900	4095	334.1	19.65	1.52	5.95	3.34	23.49	8.59	538	21.8	260			66.70	32.50
DP	3	1	1200	1398	138.3	18.62	1.49	6.27	3.71	28.38	8.79	1146	20.4	280			70.33	30.00
DP 3-02				**Katspruit**														
DP	3	2	50	26430	2630.8	16.60	1.30	6.28	3.54	25.45	9.02	808	29.2	350			61.67	36.67
DP	3	2	100	12773	1069.3	16.76	1.34	6.44	3.45	22.40	7.03	1200	27.8	450			65.43	35.00
DP	3	2	150	7375	651.4	16.03	1.15	4.47	3.11	17.29	7.8	742	35.2	320			61.60	40.00
DP	3	2	200	6435	531.2	15.77	1.12	4.63	3.28	19.79	8.24	662	30	300			59.60	37.50
DP	3	2	250	5093	415.2	16.05	1.00	4.63	3.26	20.66	8.51	508	28.4	310			63.28	35.00
DP	3	2	300	5715	345.0	18.49	1.14	5.45	3.54	18.38	8.69	564	71.8	300			64.33	35.00

Type	Transect	Zone	Depth (mm)	C av (mg/kg)	N (mg/kg)	Ca (cmol+/kg)	K (cmol+/kg)	Mg (cmol+/kg)	Na (cmol+/kg)	CEC (Na)	pH (H20)	Fe (mg/kg)	Mn (mg/kg)	Resist. (ohm)	Colour (Dry)	Colour (Wet)	Sand (0.02 - 2 mm (%)	Clay (<0.002 mm) (%)
DP	3	2	400	4958	508.8	16.97	1.10	5.45	3.63	19.68	8.64	646	71.8	310			59.88	40.00
DP	3	2	500	3993	251.3	15.46	1.03	5.12	4.11	17.83	8.7	616	57.6	320			58.98	40.00
DP	3	2	600	2990	325.6	16.76	1.06	5.45	5.13	18.38	8.92	750	61	310			61.73	36.25
DP	3	2	900	3265	247.7	11.34	1.03	5.12	7.00	16.96	8.87	712	51.2	260			56.25	42.50
DP	3	2	1200	3495	159.9	8.27	1.08	3.47	11.63	18.16	9.09	552	45.6	200			90.75	10.00
DP 3-03				**Molopo**														
DP	3	3	50	7088	700.1	1.45	0.28	0.99	3.04	6.74	9.7	406	41.8	240			85.50	16.25
DP	3	3	100	5246	517.9	3.44	0.42	1.63	7.13	5.00	9.1	244	71.6	120			79.55	21.25
DP	3	3	150	5438	568.7	10.46	0.59	2.83	11.05	10.00	9.34	272	54.8	85			75.90	25.00
DP	3	3	200	3968	341.1	7.03	0.63	2.59	13.22	11.74	9.55	310	26.2	68			73.85	27.50
DP	3	3	250	3851	219.9	6.50	0.76	2.72	16.18	22.29	9.66	120	33.4	60			73.20	27.50
DP	3	3	300	2455	179.4	12.54	0.75	2.99	16.44	12.18	9.75	150	40.2	60			74.85	25.00
DP	3	3	400	2795	285.4	3.79	0.71	2.36	16.96	11.09	9.68	80	35.6	60			70.65	30.00
DP	3	3	500	3465	130.3	14.58	0.63	2.37	16.70	10.11	9.78	216	42.2	55			73.45	26.25
DP	3	3	600	3750	130.8	17.70	0.64	2.39	17.14	11.20	9.97	286	33.6	58			72.90	27.50
DP	3	3	900	3885	259.7	21.22	0.57	2.24	12.18	8.26	9.97	372	25.8	59			70.90	27.50
DP	3	3	1200	3983	214.1	19.36	0.60	2.22	14.88	9.90	9.96	306	10.4	80			73.45	26.25

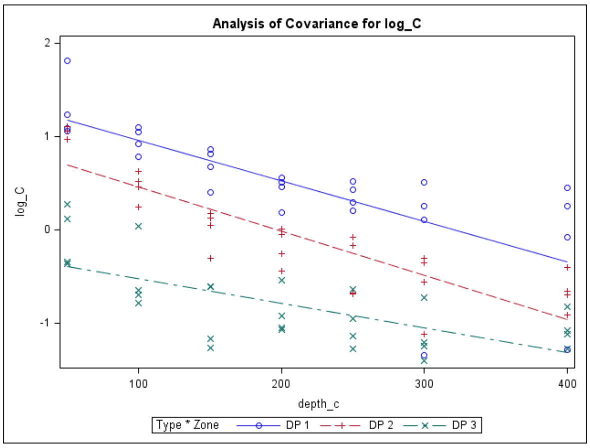
Carbon (C)



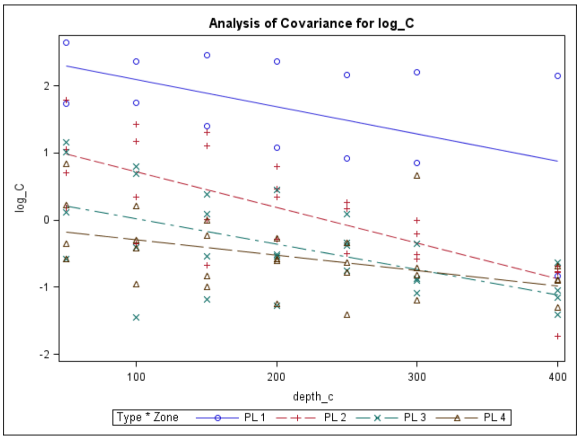
Analysis of Covariance for log_C
log_C
depth_c
Type * Zone
MS 1
MS 2
MS 3
MS 4



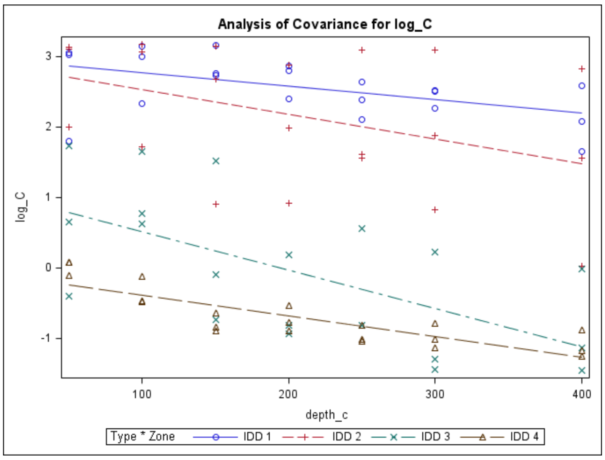
Analysis of Covariance for log_C
log_C
depth_c
Type * Zone
PP 1
PP 2
PP 3



Analysis of Covariance for log_C
log_C
depth_c
Type * Zone
DP 1
DP 2
DP 3

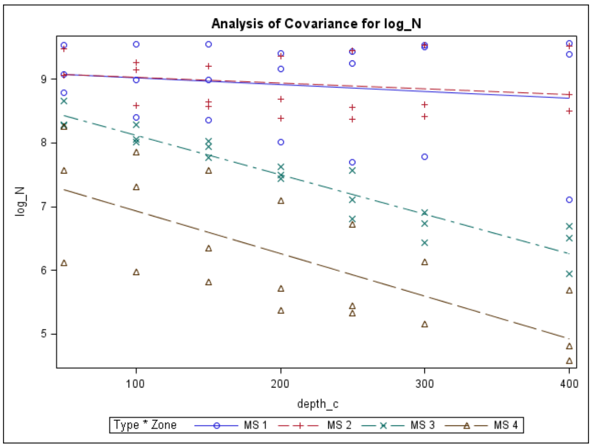


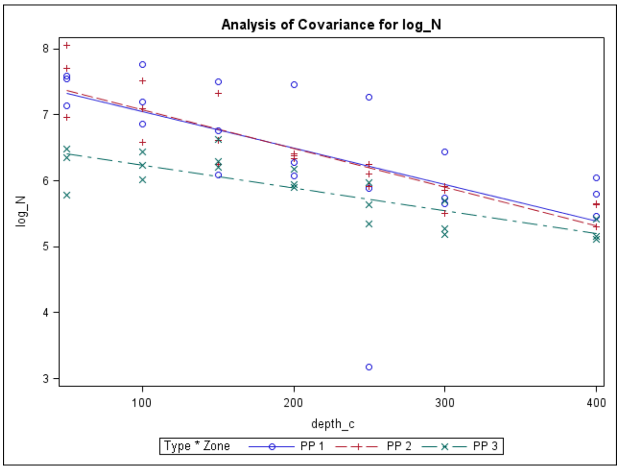
Analysis of Covariance for log_C
log_C
depth_c
Type * Zone
PL 1
PL 2
PL 3
PL 4

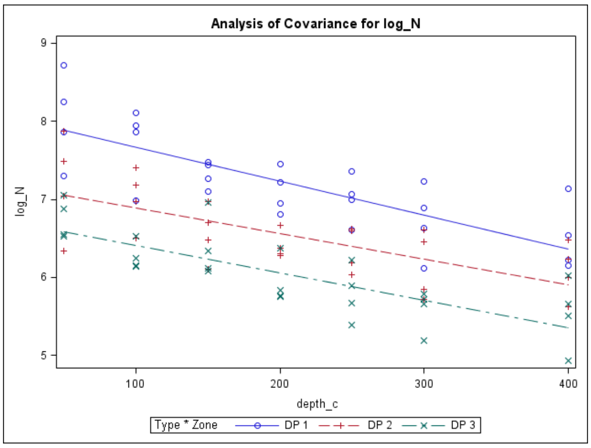


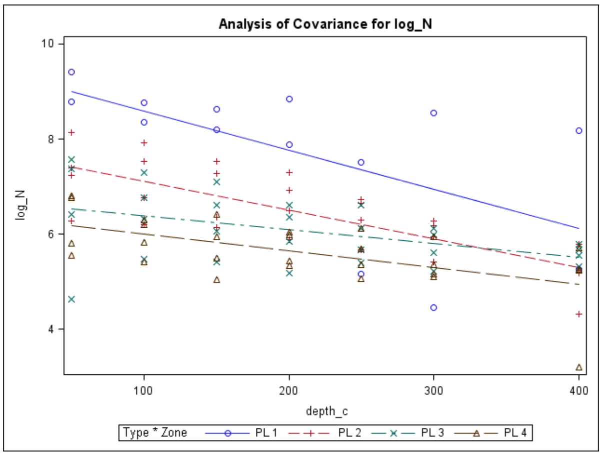
Analysis of Covariance for log_C
log_C
depth_c
Type * Zone
IDD 1
IDD 2
IDD 3
IDD 4

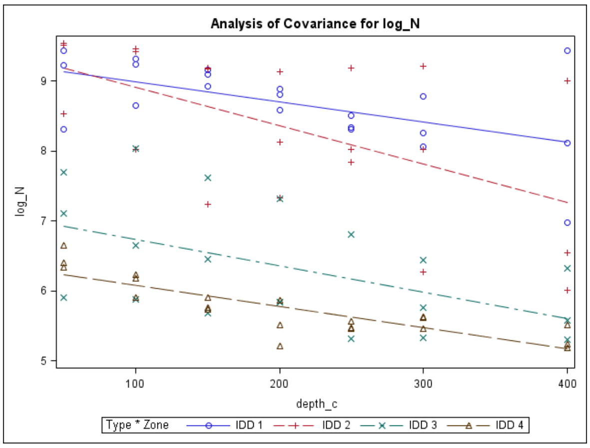
NITROGEN (N)


Analysis of Covariance for log_N
log_N
depth_c
Type * Zone MS 1 MS 2 MS 3 MS 4

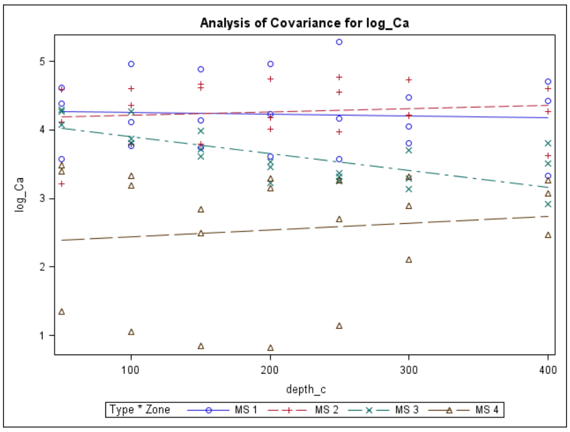

Analysis of Covariance for log_N
log_N
depth_c
Type * Zone PP 1 PP 2 PP 3


Analysis of Covariance for log_N
log_N
depth_c
Type * Zone DP 1 DP 2 DP 3

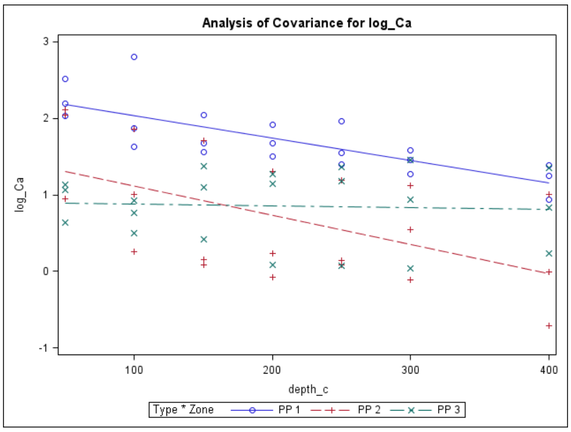

Analysis of Covariance for log_N
log_N
depth_c
Type * Zone PL 1 PL 2 PL 3 PL 4


Analysis of Covariance for log_N
log_N
depth_c
Type * Zone IDD 1 IDD 2 IDD 3 IDD 4

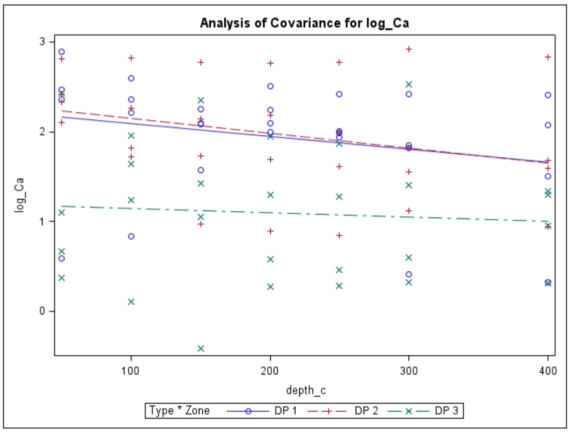
CALCIUM (Ca)



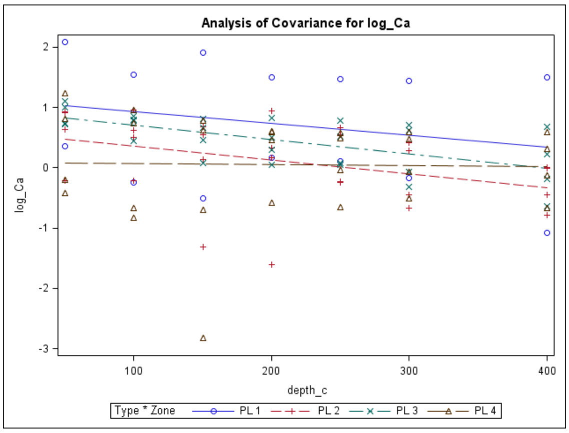
Analysis of Covariance for log_Ca
log_Ca
depth_c
Type * Zone
MS 1
MS 2
MS 3
MS 4



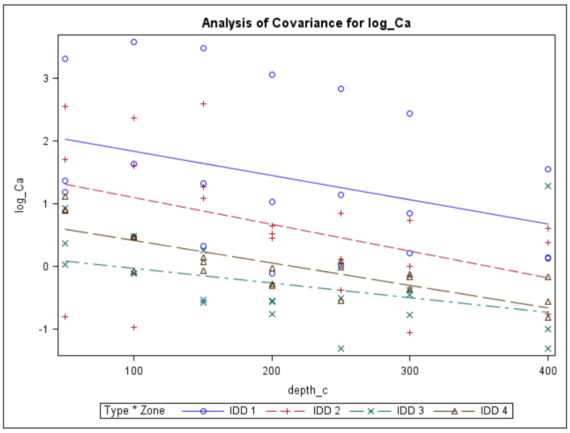
Analysis of Covariance for log_Ca
log_Ca
depth_c
Type * Zone
PP 1
PP 2
PP 3



Analysis of Covariance for log_Ca
log_Ca
depth_c
Type * Zone
DP 1
DP 2
DP 3

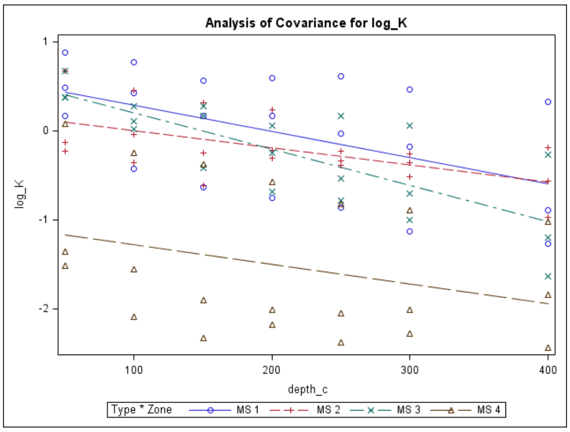


Analysis of Covariance for log_Ca
log_Ca
depth_c
Type * Zone
PL 1
PL 2
PL 3
PL 4

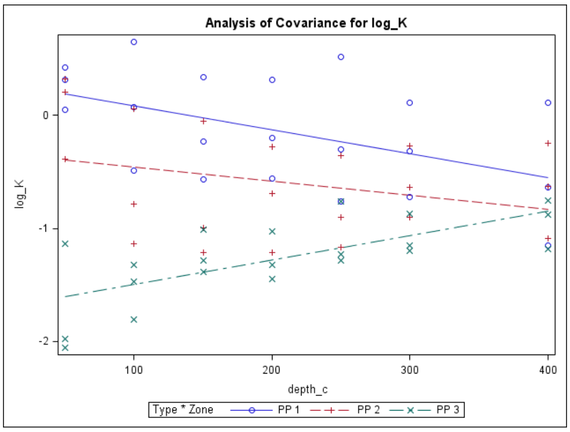


Analysis of Covariance for log_Ca
log_Ca
depth_c
Type * Zone
IDD 1
IDD 2
IDD 3
IDD 4

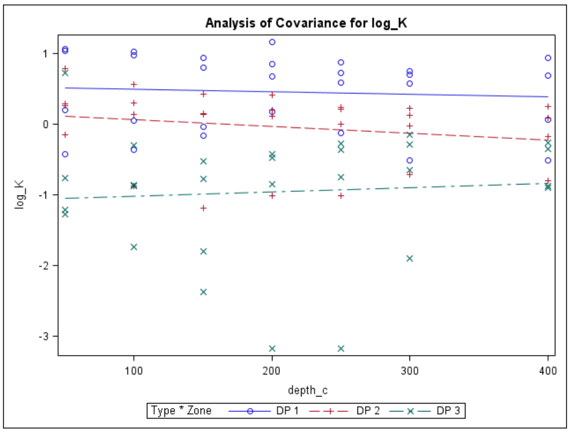
POTASSIUM (K)



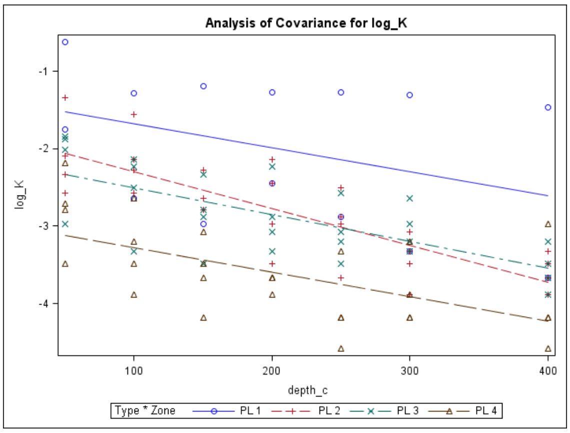
Analysis of Covariance for log_K
log_K
depth_c
Type * Zone
MS 1
MS 2
MS 3
MS 4



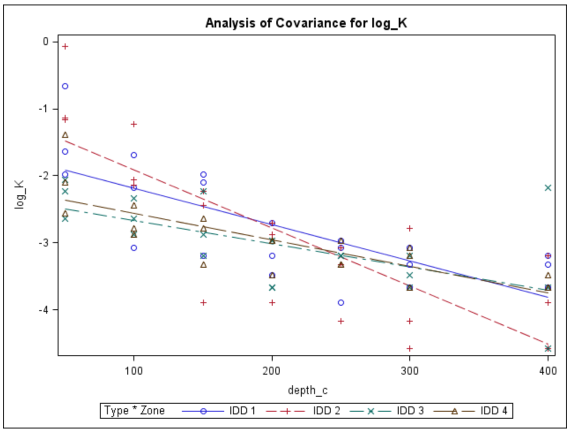
Analysis of Covariance for log_K
log_K
depth_c
Type * Zone
PP 1
PP 2
PP 3



Analysis of Covariance for log_K
log_K
depth_c
Type * Zone
DP 1
DP 2
DP 3

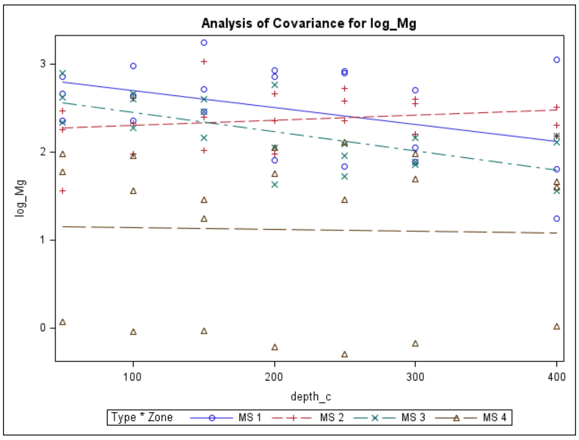


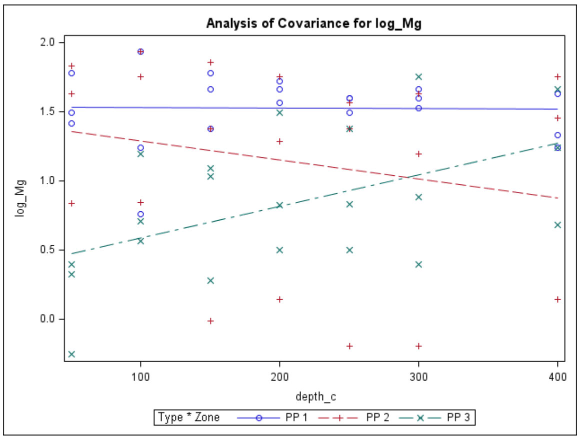
Analysis of Covariance for log_K
log_K
depth_c
Type * Zone
PL 1
PL 2
PL 3
PL 4

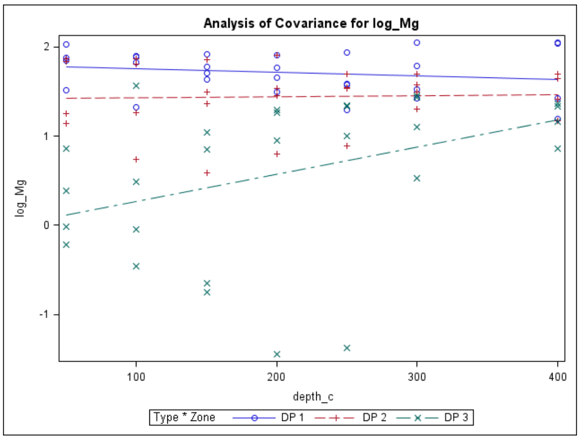


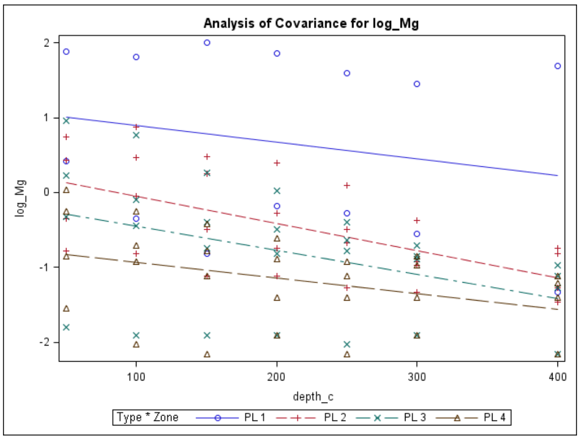
Analysis of Covariance for log_K
log_K
depth_c
Type * Zone
IDD 1
IDD 2
IDD 3
IDD 4

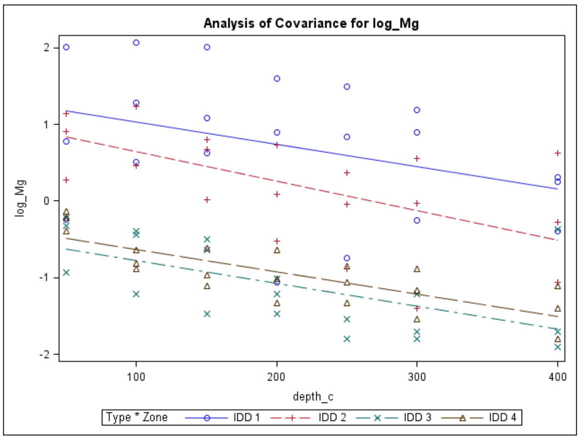
MAGNESIUM (Mg)



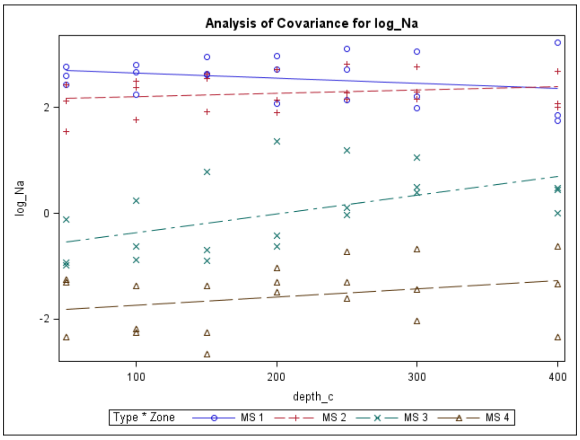




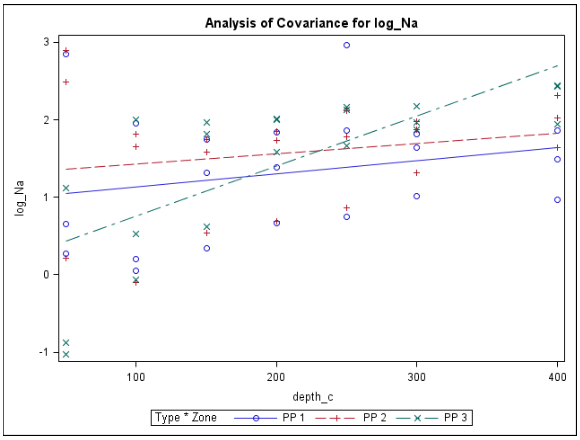




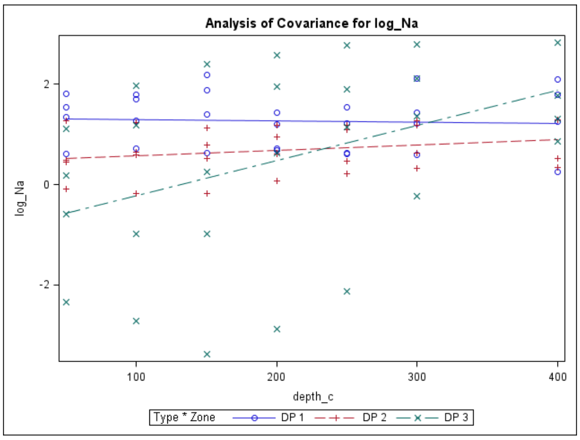
SODIUM (Na)



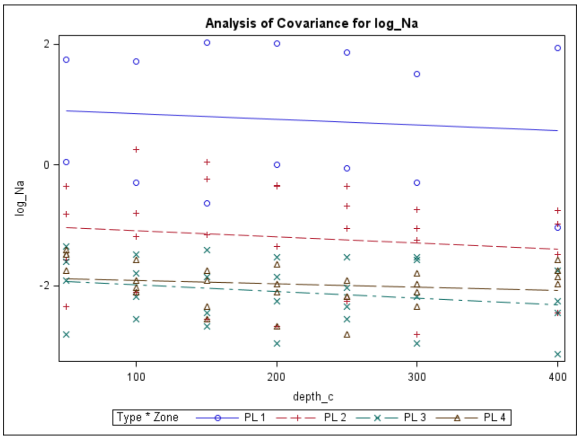
Analysis of Covariance for log_Na
log_Na
depth_c
Type * Zone
MS 1
MS 2
MS 3
MS 4



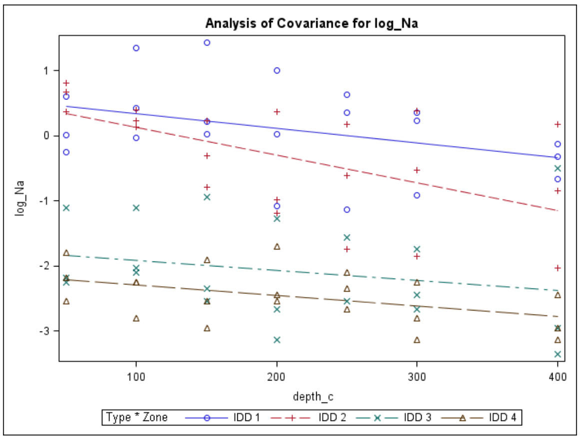
Analysis of Covariance for log_Na
log_Na
depth_c
Type * Zone
PP 1
PP 2
PP 3



Analysis of Covariance for log_Na
log_Na
depth_c
Type * Zone
DP 1
DP 2
DP 3

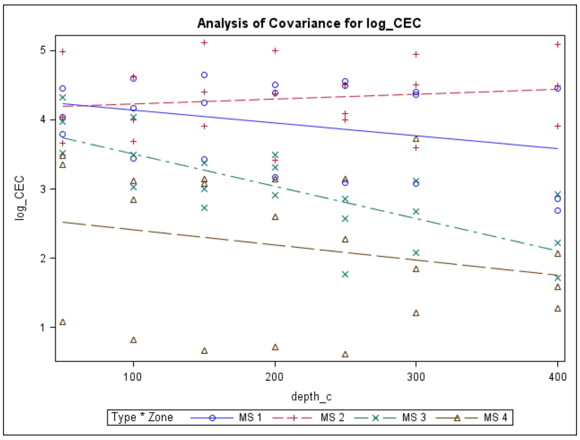


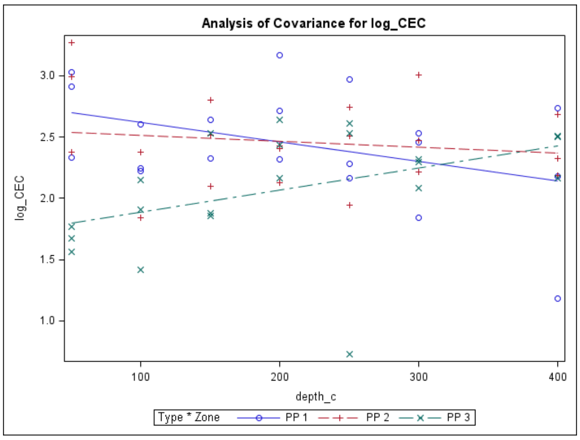
Analysis of Covariance for log_Na
log_Na
depth_c
Type * Zone
PL 1
PL 2
PL 3
PL 4

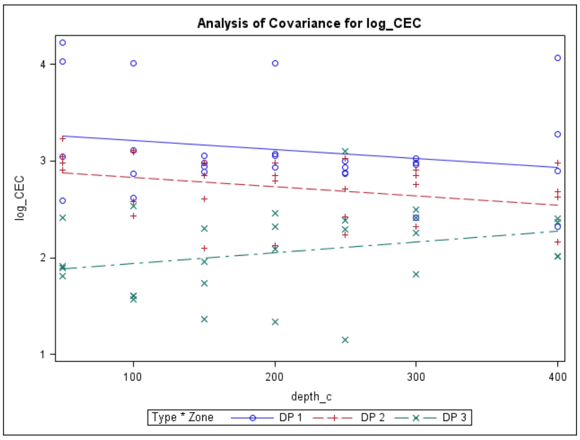


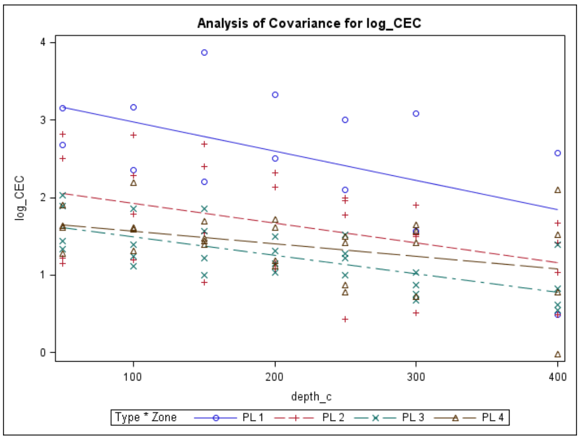
Analysis of Covariance for log_Na
log_Na
depth_c
Type * Zone
IDD 1
IDD 2
IDD 3
IDD 4

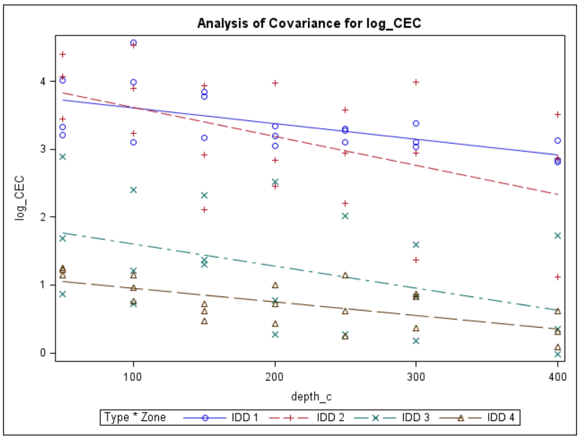
CATION EXCHANGE CAPACITY (CEC)



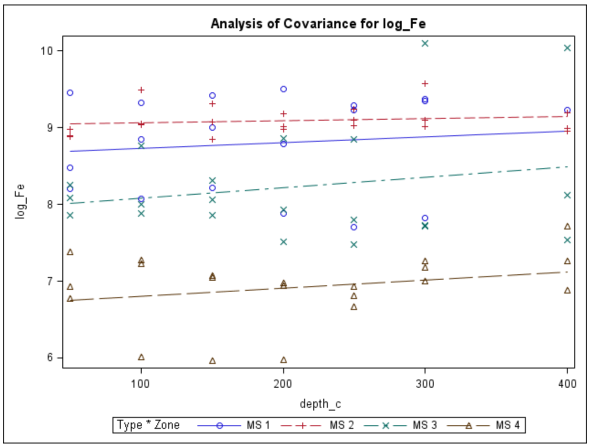


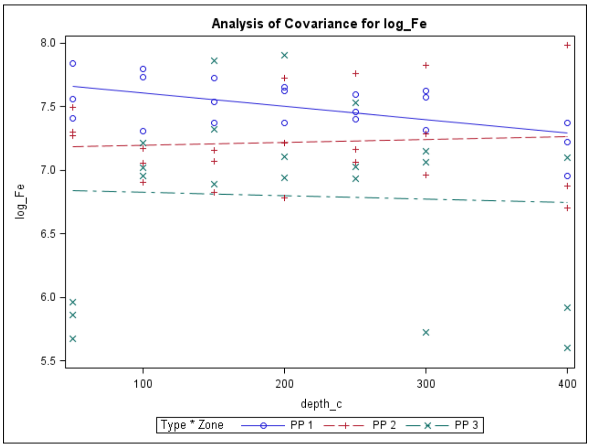


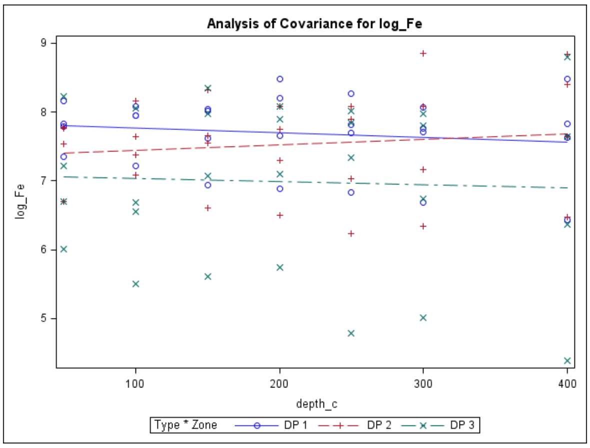


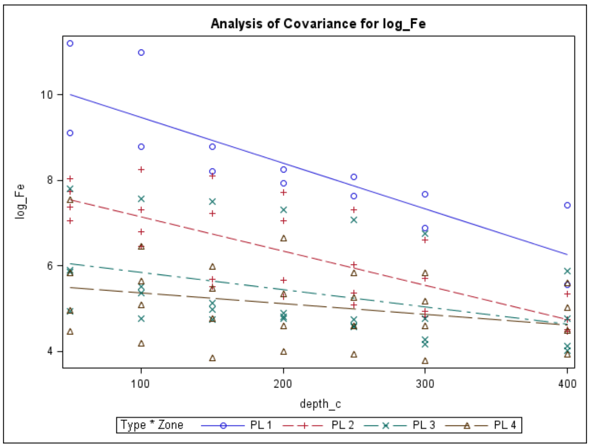


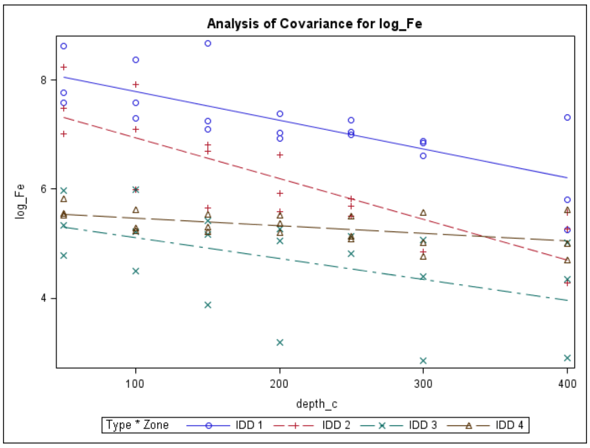
IRON (Fe)


Analysis of Covariance for log_Fe
log_Fe
depth_c
Type * Zone MS 1 MS 2 MS 3 MS 4

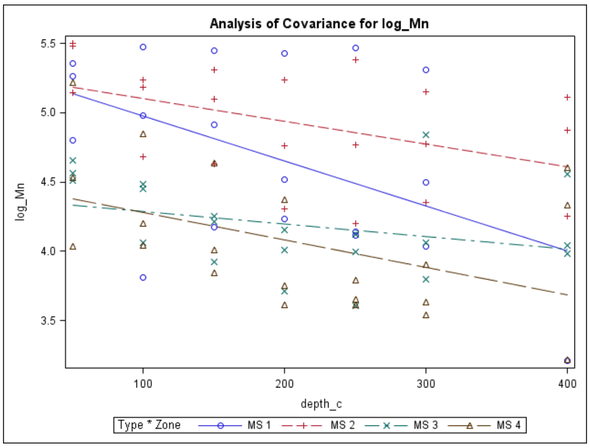

Analysis of Covariance for log_Fe
log_Fe
depth_c
Type * Zone PP 1 PP 2 PP 3

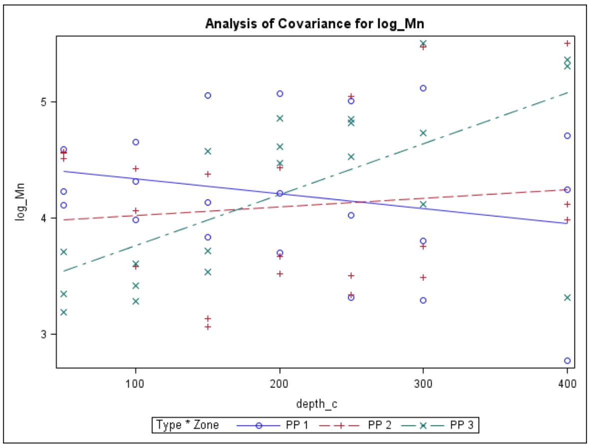

Analysis of Covariance for log_Fe
log_Fe
depth_c
Type * Zone DP 1 DP 2 DP 3

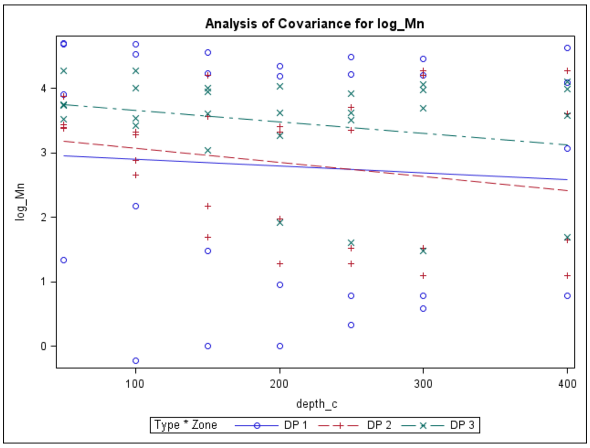

Analysis of Covariance for log_Fe
log_Fe
depth_c
Type * Zone PL 1 PL 2 PL 3 PL 4

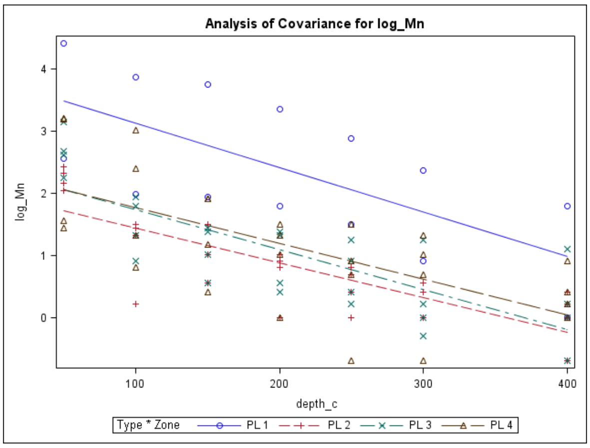

Analysis of Covariance for log_Fe
log_Fe
depth_c
Type * Zone IDD 1 IDD 2 IDD 3 IDD 4

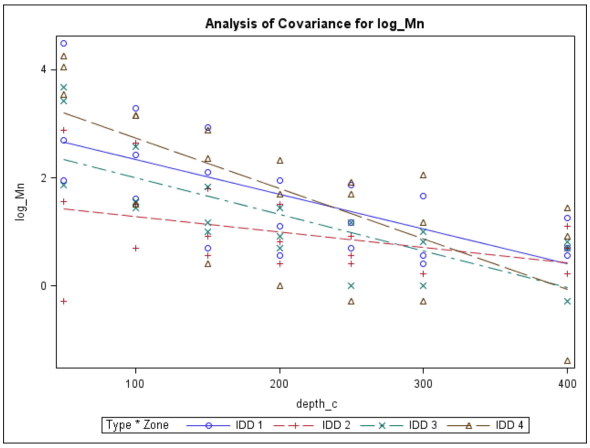
MANGANESE (Mn)



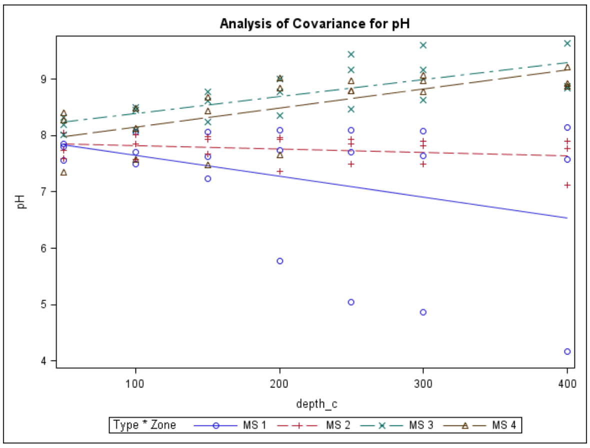


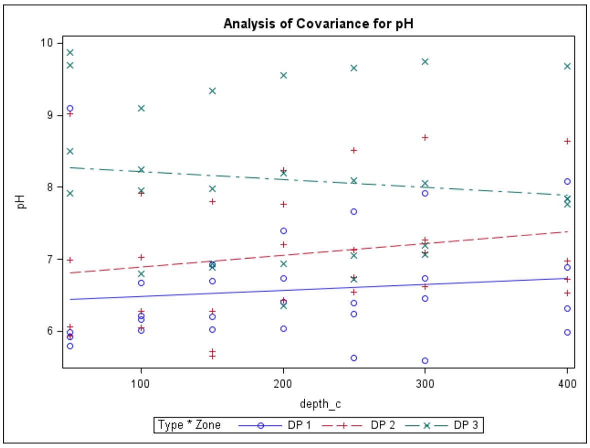


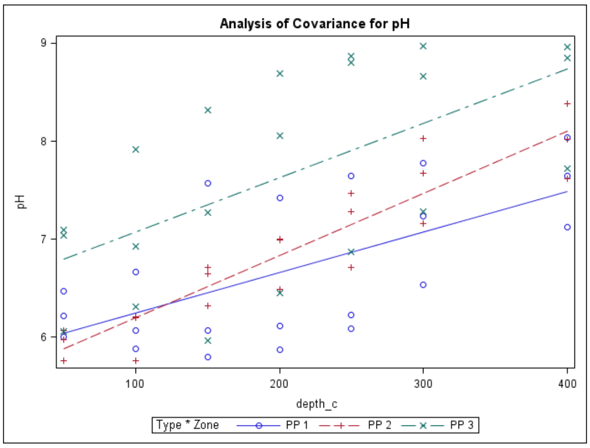


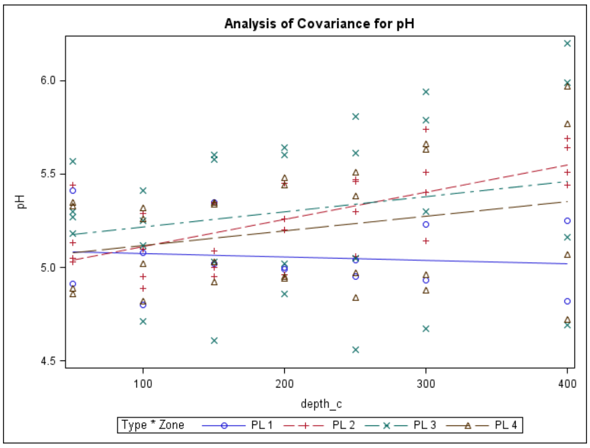


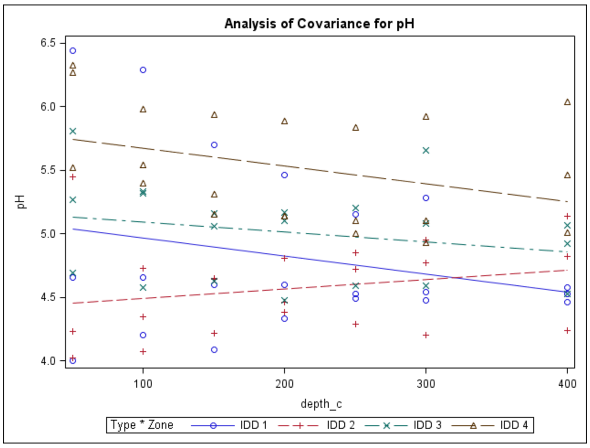
pH


Analysis of Covariance for pH
pH
depth_c
Type * Zone
MS 1
MS 2
MS 3
MS 4

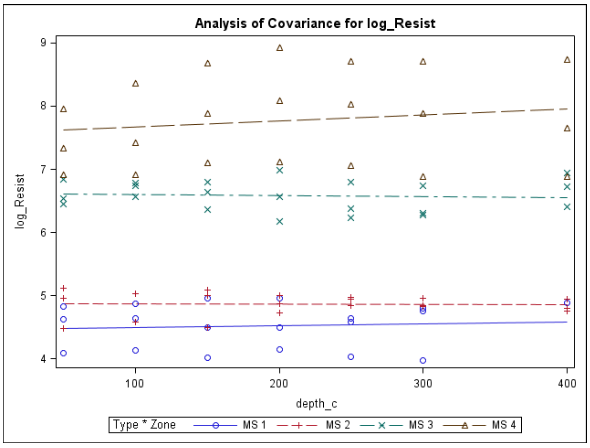

Analysis of Covariance for pH
pH
depth_c
Type * Zone
DP 1
DP 2
DP 3

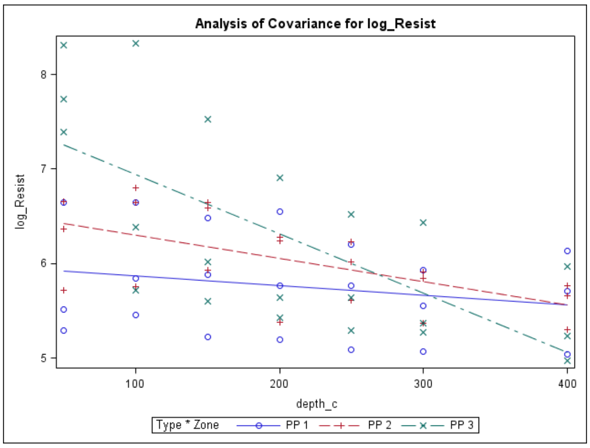

Analysis of Covariance for pH
pH
depth_c
Type * Zone
PP 1
PP 2
PP 3

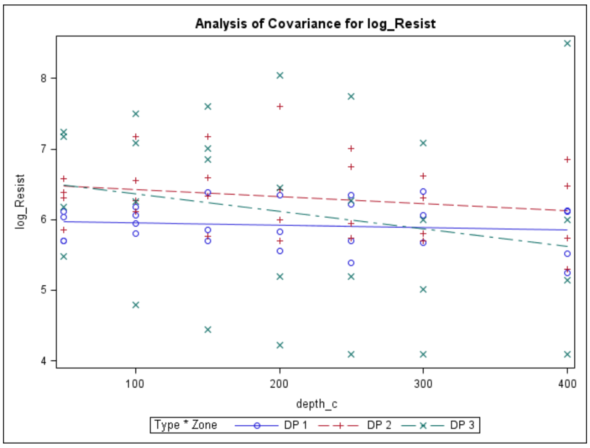

Analysis of Covariance for pH
pH
depth_c
Type * Zone
PL 1
PL 2
PL 3
PL 4

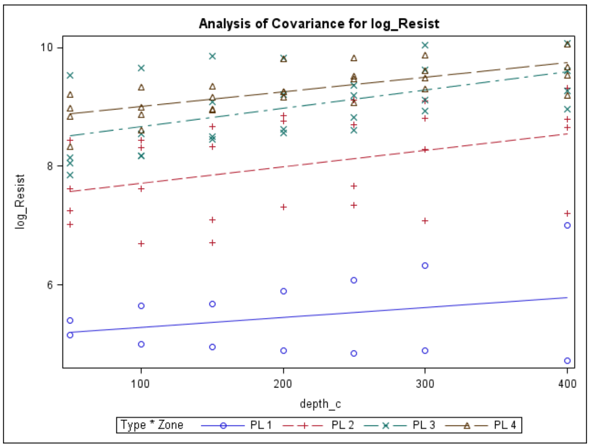

Analysis of Covariance for pH
pH
depth_c
Type * Zone
IDD 1
IDD 2
IDD 3
IDD 4

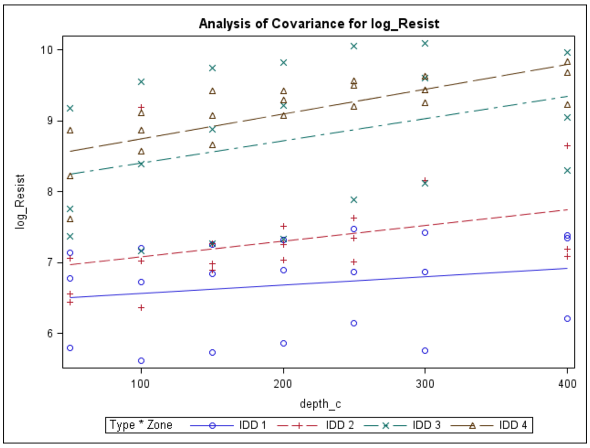
RESISTANCE


Analysis of Covariance for log_Resist
log_Resist
4
5
6
7
8
9
depth_c
100
200
300
400
Type * Zone
MS 1
MS 2
MS 3
MS 4


Analysis of Covariance for log_Resist
log_Resist
5
6
7
8
depth_c
100
200
300
400
Type * Zone
PP 1
PP 2
PP 3


Analysis of Covariance for log_Resist
log_Resist
4
5
6
7
8
depth_c
100
200
300
400
Type * Zone
DP 1
DP 2
DP 3


Analysis of Covariance for log_Resist
log_Resist
6
8
10
depth_c
100
200
300
400
Type * Zone
PL 1
PL 2
PL 3
PL 4


Analysis of Covariance for log_Resist
log_Resist
6
7
8
9
10
depth_c
100
200
300
400
Type * Zone
IDD 1
IDD 2
IDD 3
IDD 4

Community	1			2					3					4			5												6											7																		8													
sub-community																		5.1						5.2						6.1				6.2							7.1					7.2				7.3									8.1						8.2							
Relevé number	12	34	18	16	19	15	27	13	31	25	35	30	26	60	56	57	69	42	70	66	43	50	61	58	51	54	67	64	11	7	4	24	20	32	33	17	29	36	14	72	3	10	23	5	8	48	22	52	1	9	2	40	28	6	21	41	71	53	55	62	49	59	63	37	38	46	45	47	39	44	68
Species Group A																																																																							
Lemna gibba	1	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ludwigia species	2	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ludwigia adscendens subsp. *diffusa*	.	2	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lagarosiphon muscoides	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group B																																																																							
Cyperus fastigiatus	.	.	.	.	2	3	2	2	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis rotifer	.	.	.	.	1	+	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pentodon pentandrus var. *minor*	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ocimum americanum var. *americanum*	.	.	.	.	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gomphrena celasioides	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scoparia dulcis	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group C																																																																							
Echinochloa colona	.	.	.	.	.	2	.	+	.	1	4	5	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Marsilea species	1	.	.	.	.	.	.	.	4	.	2	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pistia stratiotes	.	+	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leersia hexandra	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.
Nymphaea nouchali	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Persicaria serrulata	.	.	.	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.
Species Group D																																																																							
Xyris capensis	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scleria sobolifer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Andropogon eucomus	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Lobelia anceps	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.

Elionurus muticus	. . .	. . . . .	. . . . .	+ . +	. . . . . .	. . . . + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Trychopteryx dregeana	. . .	. . . . .	. . . . .	. 1 .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. 2 . . + .	. . . .
Species Group E													
Bulbostylis contexta	. . .	. . . . .	. . . . .	. . .	2 + 1 . + +	+ + + . . +	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	+ . . . .
Cyperus obtusiflorus	. . .	. . . . .	. . . . .	. . .	+ . . + . .	+ + + + . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . + ...
Sorghastrum stipoides	. . .	. . . . .	. . . . .	5 . +	+ + 2 + . .	. . 3 . 4 .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . + .	. . 1 . 3 + . +
Syzigium cordatum	. . .	. . . . .	. . . . .	. . .	. . + . . .	. + . + + +	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Helichrysum kraussii	. . .	. . . . .	. . . . .	. . .	. + . . + .	. . . + + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . . . . + .
Agathisanthemum bojeri	. . .	. . . . .	. . . . .	. . .	+ . + . . .	. . . . + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. + ...	. . . .
Species Group F													
Ischaemum fasciculatum	. . .	. . . . .	. . . . .	. . .	. . . + . 2	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Eragrostis biflora	. . .	. . . . .	. . . . .	. . .	2 . . + . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. 3 . . . . . .
Eragrostis lappula	. . .	. . . . .	. . . . .	. . .	. . . . 3 .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Eragrostis inamoena	. . .	. . . . .	. . . . .	. . .	. . . 3 . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Eragrostis gummiflua	. . .	. . . . .	. . . . .	. . .	. . 4 . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Species Group G													
Themeda triandra	. . .	. . . . .	. . . . .	. . .	. . . . . .	2 3 . 3 . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Trachypogon spicatus	. . .	. . . . .	. . . . .	+ . +	. . . . . .	3 2 . + . 2	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Stylosanthes fruticosa	. . .	. . . . .	. . . . .	. . .	. . . . . .	+ + + + + +	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Unknown	. . .	. . . . .	. . . . .	. . .	. . . . . .	+ + + + . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Monocymbium ceresiiforme	. . .	. . . . .	. . . . .	. . .	. . . . . .	2 + . . + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Commelina africana	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + + . + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Eriosema psoraleoides	. . .	. . . . .	. . . . .	. . .	. . . . . .	+ . + + . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Andropogon chinensis	. . .	. . . . .	. . . . .	+ . .	. . . . . .	. + . + + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . +	. . . .
Chamaecrista mimosoides	. . .	. . . . .	. . . . .	. . .	. . . . . .	+ . + . . +	. . . .	. . . .	. . . . .	. . . .	. . . .	+	. . . + ...

Raphionacme hirsuta	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + . + . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Hypoxis hemerocallidea	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + + . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Species Group H													
Vernonia oligocephala	. . .	. . . . .	. . . . .	. . .	. . . . + .	+ + 2 . . +	+ + + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Cymbopogon excavatus	. . .	. . . . .	. . . . .	. . .	. . . . . .	+ 1 . + + +	. . 1 .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Phoenix reclinata	. . .	. . . . .	. . . . .	. . .	. . + . . .	. + . + + .	+ r . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Perotis patens	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + . . . +	. . . +	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Setaria sphacelata	. . .	. . . . .	. . . . .	. . .	+	. 1 . . . +	. + . .	. . + ...	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Vernonia natalensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . + . . +	+ . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Species Group I													
Acacia karroo	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. 1 + .	4 . . 2 + . 2	. . . . .	. . . .	. . + ...	. . . . . .	. . . .
Acacia nilotica	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	1 + . +	. . + + . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Species Group J													
Hyperthelia dissoluta	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	3 2 2 2	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Acalypha villicaulis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . +	1 + + .	. . . .	. + . . .	. . . .	. . . .	. . . . . .	. . . .
Eragrostis superba	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	+ + + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Justicia betonica	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. + + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Phyllanthus maderaspatensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	+ . + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Helichrysum nudifolium	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . +	+ . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Litogyne gariepina	. . .	+	. . . . .	. . .	. . . . . .	. . . . . .	+ . + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Species Group K													
Justicia flava	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	+ + + + + + .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Panicum maximum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	3 . . 3 . . 1	. . . . .	. . . .	. . . .	. . . + . .	. . . .
Euclea undulata	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	+ . + + . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Spirostachys africana	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	+ . . + . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Nidorella hottentotica	. . .	. + . . .	. . . . .	. . .	. . . . . .	. . . . + .	. . . .	. + . + . + .	. . . . .	. . . .	. . . .	. + ...	. . . .
Solanum panduriforme	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . . 2 + .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Ziziphus mucronata	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . + . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .

Euclea natalensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	+ . . + . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Phyllobolus congestus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . 1	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Species Group L													
Phragmites australis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. + 1 . +	+ . + .	4 1 r . . + 5 . +	. . . + . .	. . . .
Dactyloctenium aegyptium	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. + . +	. . . . . + +	. 2 . 3 2	+ . + .	+ 4 1 . . 5 + . .	. . . . . .	. + ... + .
Phyla nodiflora	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . + . 1	. . + .	3 . + 1 . 1 1 . 2	. . . . . .	. . . .
Conyza canadensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . + .	+ . + .	+ . + . . + + . .	. . . . + .	. . . .
Hydrocotyle bonariensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	 2	+ . + .	. . . . . + + . .	+	. . . .
Species Group M													
Imperata cylindrica	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	5 4 5 3 4	. . . .	. . . .	2	. . . .
Cymbopogon validus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. + . +	. . . .	. . + + 1	. . . .	. . . .	. . . . . .	. . . .
Corchorus asplenifolius	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	+ + . .	. . . .	. . + + .	. . . .	. . . .	. . . . . .	. . . .
Species Group N													
Cladium mariscus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	5 4 4 5	. . 4	. . . + . .	. . . .
Fimbristylis ferruginea	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . + .	. . . .	. . . . . .	. . . .
Pelargonium spp	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	+ . . .	. . . .	. . . . . .	. . . .
Chromolaena odorata	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	r . . .	. . . .	. . . . . .	. . . .
Species Group O													
Stenotaphrum secundatum	. . .	. . . . .	. . . . .	. . .	. 2	. . . . . .	. . . .	. 1 + ...	. . . . .	. . . .	. 4 . + 4 2 . 2 4	. . . . . .	b . . . . + 2 .
Gomphocarpus fruticosa	. . .	. r . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . + + . r + + .	. + + . . .	. . . .
Hibiscus trionum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. + . . .	. . . .	. . + . + + . . .	. . . . . .	. . . .
Hibiscus diversifolius subsp. diversifolius	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	1 . . .	. . 1 . . + + . .	. . . . . .	. . . .
Ethulia conyzoides subsp. kraussii	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	+ . . .	. . + . . . + . 1	. . . . . .	. . . .
Flaveria bidentis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . +	. . + .	. . + . . . + . .	. . . . . .	. . . .
Species Group P													

Hemarthria altissima	. . .	. . . . .	. . . . .	. . .	. . . + . .	. . . . . .	. . . .	. . . .	 2	. 2 . .	. . . .	. + + 4 5 5	. . 4 4 . . . .
Unknown	. . .	. . . . .	. . . . .	. . .	+	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. 5 + 2 . 2	 1
Cyperus sphaerospermus	. . .	. . . . .	. . . . .	. . .	+ . . . . +	. . . + . .	. . . .	. . . .	1	. . . .	. . . . . + . . .	+ . 3 + . +	. + . . + 1 . .
Pycreus polystachyos var. *polystachyos*	. . .	. . . . .	. . + . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . 1 . . . 1 .	. . + . . .	. . . + ...
Species Group Q													
Thelypteris interrupta	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	1	. . . .	. . + ...	1 1 2 + 2 .	. . . .
Rhynchospora holoschoenoides	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	+ + + . . +	. . . .
Dissotis canescens	. . .	. . . . .	. . . . .	. + .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . +	. . . .	3 2	. . . .
Helichrysum aureum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	1 . + . + .	. . . . . . + .
Persicaria lapathifolia	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . 2 . . +	. . . .
Schoenoplectus corymbosus	. . .	. . . . .	. . . . .	+ . .	. . . . . .	+ + ...	. . . .	. . . .	. . . . .	. . . .	. . . .	. . 3 . . .	. . . .
Blumea dregeanoides	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. + . .	. . . .	. + + . . .	. . . .
Species Group R													
Unknown	. . .	. . . . .	. . . . .	. . .	. 3	. . . . . .	. . . .	. . . .	+	. . . .	. . . .	. . . . . .	. 4 . 1 1 . 4 .
Cyperus obtusiflorus var. *obtusiflorus*	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. + . + . + . .
Crotalaria lanceolata subsp. *lanceolata*	. . .	. . . . .	. . . . .	. . .	. + ...	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . . 1 . . .
Sporobolus subtilis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	1 . . . .
Urochloa mossambicensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . + . . + . .
Species Group S													
Centella asiatica	. . .	. . . . .	. . + . .	. . .	+ . . 2 + +	+ . . + . .	. . . .	. . . .	. . . . .	. 1 1 .	+ + . 3 + + . 2 .	+ . . 1 . +	1 + + 4 + 2 2 4
Eclipta prostrata	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	+ . . .	+ . 1 . + . . 1 .	+ . 1 + . .	. . 1 + + + . .
Species Group T													
Cyperus natalensis	. . .	. . . . .	3 . 1 . .	. . .	2 3 + . + 1	. . . . + .	. . . .	. + . . + . .	. . . . .	. . . .	. . . .	. 1 2 + . 1	4 1 2 2 + . + +
Dichrostachys cinerea	. . .	. . . . .	. . . . .	. . .	. + + . . .	. . . . + .	. + . 2	. . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Digitaria eriantha	. . .	. . . . .	. . . . .	. . .	. . . . + .	+ + + 2 . +	. . + +	+ . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .

Unknown	. . .	. . . . .	. . . . .	. . .	. . . . . .	+ . . + . .	. + . .	. . . .	. . . + .	. . . .	. . . .	. . . . . .	. . . .
Cynodon dactylon	. . .	2 + + . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	2 5 4 . 4 4 2	. . . 1 +	. . . .	3 . 3 5 2 . . 4 .	. . . . . .	. . . .
Eragrostis heteromera	. . .	. . . . .	. . . . .	. . .	+ 1 . . + .	. . . . . .	+ + 2 .	. + + . + + .	. . . . .	. . . .	. . . . . + . . .	. . . . . .	. + + . 2 4 . .
Commelina erecta	. . .	+	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Xanthium strumarium	. . .	. . . + .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Tragus berteronianus	. . .	. + . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Alternanthera pungens	. . .	+	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Unknown	. . .	. . . . +	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Persicaria attenuata	. . .	. . . . .	. . + . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . . + ...	. . . . . .	. . . .
Oxalis species	. . .	. . . . .	. . . . +	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Fuirena umbellata	. . .	. + . . .	. . + . .	. . .	. . . . . .	. . . . . .	. . . .	. + ...	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Vahlia capensis	. . .	. . . . .	. . . . .	. . .	+	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Gazania krebsiana	. . .	. . . . .	. . . . .	. . .	. . . + . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Indigofera species	. . .	. . . . .	. . . . .	. . .	+	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Waltheria indica	. . .	. . . . .	. . . . .	. . .	. + ...	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Helichrysum setosum	. . .	. . . . .	. . . . .	. . .	. + ...	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Cyperus rupestris	. . .	. . . . .	. . . . .	. . .	. . + . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Cephalaria zeyheriana	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + ...	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Diospyros lycioides	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Wahlenbergia abyssinica	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Hypericum lalandii	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + ...	. . . .	. . . .	. . . . .	. . . .	. . . .	. + ...	. . . .
Tephrosia linearis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + ...	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . + ...
Albuca species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . + . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Pteridium aquilinum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + ...	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Gladiolus species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . + . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Senecio erubescens	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . + . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Trichoneura grandiglum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . + .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Oxygonum dregeanum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. + ...	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Aspidoglossum delagoense	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . + . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Phyllanthus parvulus var. *parvulus*	. . .	. . . . .	. . . . .	. . .	. . + . . .	. . . . . .	. + . .	. . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .

Justicia anagalloides	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Setaria pumila	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. + . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Kyllinga alba	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . +	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Sporobolus africanus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . +	. . . . . + .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Aristida stipitata	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . +	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Chrysopogon serrulatus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	+ . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Striga elegans	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. + . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Xenostegia tridentata	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . r	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Diheteropogon amplectens	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. + . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Indigophera torulosa	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Astripomoea malvacea	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. + . .	. . . .	. . . . .	. . . .	. . . .	. . . . . +	. . . .
Lantana rugosa	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . + .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Cucumis zeyheri	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . +	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Melhania forbesii	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Sansevieria concinna	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . + ...	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Blepharis integrifolia	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . + ...	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Cyperus solidus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Gymnosporia buxifolia	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Aloe species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . + ...	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Berchemia zeyheri	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Solanum incanum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. + ...	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Convolvulus species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. + ...	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Schotia brachypetala	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	+	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Cyathula cylindrica var. *cylindrica*	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . . + . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Conyza bonariensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. + ...	. . . . .	. . . .	. . . . + ...	. . . . . .	. . . .
Achyranthes aspera var. *sicula*	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . . . . +	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Enicostema axillare	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . + .	. . . .	. + . . .	. . . .	. . . .	. . . . . .	. . . .
Polygala species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . + .	. . . .	. . . .	. . . . . .	. . . .
Unknown	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . + + ...
Unknown	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . + + . .	. . . .

Commelina benghalensis	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	+	. . . .
Ludwigia leptocarpa	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . + . . .	. . . .
Senecio species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . + . . .	. . . .
Fuirena species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . + . . .	. . . .
Sonchus oleraceus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . . + .	. . . . . .	. . . . . + . .
Helichrysum rugulosum	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . .	. . . . . .	. . . .
Solanum sysimbrifolium	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . + ...	. . . . . .	. . . .
Sida alba	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . . + ...	. . . . . .	. . . .
Hibiscus cannabinus	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . . r	. . . . . .	. . . .
Aeschynomene species	. . .	. . . . .	. . . . .	. . .	. . . . . .	. . . . . .	. . . .	. . . .	. . . . .	. . . .	. . . . + ...	. . . . . .	. . . .
Hyphaene coriacea	. . .	. . . . .	. . . . .	. . .	. . + . . .	. . . . + .	. . . +	. . . + . . +	. . . . r	. . . .	. . . .	. . . . . .	. . . .

Species	Wetland Dependence
Acacia karroo	Upland
Acacia nilotica	Upland
Acalypha villicaulis	Upland
Achyranthes aspera var. *sicula*	Upland
Agathisanthemum bojeri subsp. *bojeri*	Facultative +
Alternanthera pungens	Upland
Andropogon chinensis	Upland
Andropogon eucomus	Obligate wetland plant
Aristida stipitata subsp. *graciliflora*	Facultative Upland
Aspidoglossum delagoense	Upland
Astripomoea malvacea	Facultative +
Berchemia zeyheri	Upland
Blepharis integrifolia	Upland
Blumea dregeanoides	Facultative wetland plant
Bulbostylis contexta	Upland
Centella asiatica	Facultative wetland plant
Cephalaria zeyheriana	Facultative +
Chamaecrista mimosoides	Upland
Chromolaena odorata	Upland
Chrysopogon serrulatus	Upland
Cladium mariscus subsp. *jamaicense*	Obligate wetland plant
Commelina africana	Upland
Commelina benghalensis	Upland
Commelina erecta	Facultative wetland plant—
Convolvulus species	Upland
Ipomoea cairica	Facultative wetland plant
Ipomoea ficifolia	Facultative wetland plant—
Ipomoea indica	Facultative wetland plant—
Ipomoea ochracea var. *ochracea*	Facultative wetland plant—
Conyza bonariensis	Upland
Conyza canadensis	Upland
Corchorus asplenifolius	Upland
Crotalaria lanceolata subsp. lanceolata	Upland
Cucumis zeyheri	Upland
Cyathula cylindrica var. *cylindrica*	Upland
Cymbopogon caesius	Facultative wetland plant—
Cymbopogon caesius	Facultative wetland plant—
Cymbopogon nardus	Facultative wetland plant
Cynodon dactylon	Facultative wetland plant+
Cyperus fastigiatus	Obligate wetland plant
Cyperus natalensis	Obligate wetland plant
Cyperus obtusiflorus	Upland
Cyperus obtusiflorus var. obtusiflorus	Upland
Cyperus rupestris	Opportunist plant
Cyperus solidus	Facultative wetland plant
Cyperus sphaerospermus	Facultative wetland plant+
Dactyloctenium aegyptium	Opportunist plant
Dichrostachys cinerea	Upland
Digitaria eriantha	Upland
Diheteropogon amplectens	Upland
Diospyros lycioides	Upland
Dissotis canescens	Obligate wetland plant
Echinochloa colona	Facultative wetland plant+
Eclipta prostrata	Obligate wetland plant
Elionurus muticus	Facultative wetland plant
Enicostema axillare subsp. axillare	Facultative wetland plant
Eragrostis biflora	Upland
Eragrostis gummiflua	Upland

Eragrostis heteromera	Facultative wetland plant—
Eragrostis inamoena	Obligate wetland plant
Eragrostis lappula	Facultative wetland plant
Eragrostis rotifer	Facultative wetland plant
Eragrostis superba	Upland
Eriosema psoraleoides	Upland
Ethulia conyzoides subsp. conyzoides	Facultative wetland plant
Euclea natalensis	Upland
Euclea undulata	Upland
Fimbristylis ferruginea	Obligate wetland plant
Flaveria bidentis	Upland
Fuirena species	Obligate wetland plant
Fuirena umbellata	Obligate wetland plant
Gazania krebsiana	Upland
Gomphocarpus fruticosus subsp. fruticosus	Facultative wetland plant—
Gomphrena celosioides	Facultative wetland plant
Gymnosporia buxifolia	Upland
Helichrysum aureum	Upland
Helichrysum kraussii	Upland
Helichrysum nudifolium var. nudifolium	Facultative wetland plant—
Helichrysum rugulosum	Upland
Helichrysum setosum	Upland
Hemarthria altissima	Obligate wetland plant
Hibiscus cannabinus	Opportunist plant
Hibiscus diversifolius subsp. diversifolius	Obligate wetland plant
Hibiscus trionum	Opportunist plant
Hydrocotyle bonariensis.	Obligate wetland plant
Hypericum lalandii	Facultative wetland plant+
Hyperthelia dissoluta	Upland
Hyphaene coriacea	Upland
Hypoxis hemerocallidea	Upland
Imperata cylindrica	Facultative wetland plant+
Indigofera species	Facultative
Indigofera torulosa	Upland
Ischaemum fasciculatum	Obligate wetland plant
Justicia anagalloides	Upland
Justicia betonica	Facultative wetland plant—
Justicia flava	Upland
Kyllinga alba	Upland
Lagarosiphon muscoides Hav.	Obligate wetland plant
Lantana rugosa	Upland
Leersia hexandra	Obligate wetland plant
Lemna gibba	Obligate wetland plant
Litogyne gariepina	Upland
Lobelia anceps	Obligate wetland plant
Ludwigia adscendens subsp. diffusa	Obligate wetland plant
Ludwigia leptocarp	Obligate wetland plant
Ludwigia species	Obligate wetland plant
Marsilea species	Obligate wetland plant
Melhania forbesii	Upland
Monocymbium ceresiiforme	Facultative wetland plant
Nidorella hottentotica	Upland
Nymphaea nouchali	Obligate wetland plant
Ocimum americanum var. americanum	Upland
Oxalis species	Upland
Oxygonum dregeanum	Upland
Panicum maximum	Facultative wetland plant—
Pentodon pentandrus	Obligate wetland plant
Perotis patens	Upland

Persicaria attenuata subsp. africana	Obligate wetland plant
Persicaria lapathifolia	Facultative wetland plant
Persicaria decipiens	Obligate wetland plant
Phoenix reclinata	Upland
Phragmites australis	Obligate wetland plant
Phyla nodiflora var. nodiflora	Obligate wetland plant
Phyllanthus maderaspatensis	Upland
Phyllanthus parvulus var. parvulus	Upland
Phyllobolus congestus	Upland
Pistia stratiotes	Obligate wetland plant
Polygala species	Upland
Pteridium aquilinum subsp. aquilinum	Facultative wetland plant+
Pycreus polystachyos var. polystachyos	Obligate wetland plant
Raphionacme hirsuta	Upland
Rhynchospora holoschoenoides	Obligate wetland plant
Sansevieria concinna	Upland
Schoenoplectus brachyceras	Obligate wetland plant
Schotia brachypetala	Upland
Scleria sobolifer	Obligate wetland plant
Scoparia dulcis	Upland
Senecio erubescens	Upland
Senecio species	Upland
Setaria pumila	Facultative wetland plant—
Setaria sphacelata v ar. sphacelata	Facultative wetland plant—
Sida alba	Upland
Solanum incanum	Upland
Solanum panduriforme	Upland
Solanum sysimbrifolium	Upland
Sonchus oleraceus	Upland
Sorghastrum stipoides	Facultative wetland plant—
Spirostachys africana	Upland
Sporobolus africanus	Facultative wetland plant—
Sporobolus subtilis Kunth	Facultative wetland plant+
Stenotaphrum secundatum	Facultative wetland plant+
Striga elegans	Upland
Stylosanthes fruticosa	Upland
Syzigium cordatum	Upland
Tephrosia linearis	Upland
Thelypteris interrupta	Upland
Themeda triandra	Upland
Trachypogon spicatus	Upland
Tragus berteronianus	Upland
Trichoneura grandiglum	Upland
Trychopteryx dregeana	Upland
Urochloa mossambicensis	Upland
Vahlia capensis	Upland
Vernonia natalensis	Upland
Vernonia oligocephala	Upland
Wahlenbergia abyssinica	Upland
Waltheria indica	Upland
Xanthium strumarium	Upland
Xenostegia tridentata	Upland
Xyris capensis Thunb.	Obligate wetland plant
Ziziphus mucronata	Upland